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PART IV.

Official Papers.

IRON INDUSTRY IN INDIA.

DEPARTMENT OF FINANCE AND COMMERCE.

NOTIFICATION.

Simla, the 4th August 1882.

No. 2899.

RESOLUTION—By the Government of India, Department of Finance and Commerce.

Read—

Note by Mr. T. C. Hope, Secretary to the Government of India in the Department of Finance and Commerce, on the Iron Industry in India.

Despatch to Her Majesty's Secretary of State for India, No. 175, dated 1st July 1881, recommending the purchase of the Bengal Iron Works.

Despatch from Her Majesty's Secretary of State for India, No. 40, dated 25th August 1881, sanctioning the purchase.

Report on the Bengal Iron Works, by Ritter C. von Schwarz, dated 26th October 1881. Telegram from the Government of Bengal in the Public Works Department, dated 5th April 1882, reporting conclusion of negotiations for purchase.

Letter to the Government of Bengal, Public Works Department, No. 494, dated 19th April, regarding temporary charge of the Works, and calling for report on condition and utilization of works.

Letter from the Government of Bengal, No. 2343 E., dated 14th July 1882, furnishing reports by Ritter C. von Schwarz, with Memorandum by the Chief Engineer.

RESOLUTION.—The Government of India have, for some time past, had under special consideration the importance of developing the iron industry in India. The advantages which such development would afford to both the State and the public,—by cheapening the cost of railway construction and maintenance, and of works for improving the water-supply; by substituting metal for more perishable materials in buildings; by reducing the home charges and their concomitant loss by exchange; by creating for the population non-agricultural employment; and by increasing the means for profitable investment of capital,—are too well known to require lengthened exposition.

2. Regarding the capabilities of the Indian iron measures to fulfil all that is required of them, no doubt can reasonably be entertained. Moreover, they lie, for the most part, in convenient proxi-

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mity to either ample supplies of coal or forests available for use in the preparation of the ore. In Assam, Kuch Behar, Burma, and the Kumaon ranges the prospects are promising to a greater or less extent. In Lower Bengal, the Raniganj district, Sonthalia, and Chutia Nagpur; in the Central Provinces, Sambalpur and Chanda; in Central India, the ranges near Gwalior; and in the Punjab, numerous localities, are found to be specially endowed with all the requisites for successful production. In quality the ores are mostly found to be extremely pure; and where the proportion of phosphorous and other impurities is large, recently invented processes have removed all obstacle to their successful elimination.

3. Under the circumstances above described, it may be accepted as proved that India possesses the means of supplying all her wants in respect of cast iron, wrought iron and steel, and that such supply could be produced remuneratively on a strictly commercial basis. The establishment of iron works to be owned and worked by the State is open to grave objections, both economic and practical, and being likewise unnecessary, need not be discussed at length. Nothing appears to be necessary in order to attract private enterprise to so eligible an opening except the collection and diffusion of sufficient information, and the grant of such facilities as the State may legitimately and reasonably afford to a young and growing industry.

4. Private enterprise in this matter, however, must evidently be on a large scale, and not confined to one locality alone. The distances in India are so great, and the railway system now so extended, that the cost of conveying material to the spot where it is needed is an important factor in every calculation. It has been proved that, unless mills were established in four different localities, the cost of sending old rails and tyres to be worked up afresh would exceed that of obtaining new ones from England. A similar conclusion has been formed as to the gain by substituting iron sleepers for wooden ones. Raniganj, the Punjab and the Central Provinces appear to be the localities in all of which extensive operations would be necessary in order to meet early necessities of the case. Whether these localities should be occupied by different Companies or by one is a matter of detail, but the aggregate capital required would obviously be large. The amount required might perhaps be beyond the local resources of the Calcutta or Bombay money market, and the investment uncongenial to those in Europe with whom those markets are connected in their ordinary mercantile transactions. England must likewise be looked to, and those capitalists in England whose knowledge and resources are specially directed to the iron industry.

5. Towards the development of the industry in the Raniganj district, the attention of the Government has in the first instance been directed, in consequence of the fact that a private Company was established a few years ago near Barrakur, but after a short time fell into difficulties from causes which need not be related, and was obliged to suspend operations. After carefully investigating the causes of failure, the Government of India came to the conclusion that the only way in which the works could be, at any early date, placed in the hands of experienced persons having an adequate command of capital, was by an intermediate purchase on the part of the State.

6. The "Bengal Iron Works" have consequently been purchased for the sum of Rs. 4,30,761. His Excellency the Governor General in Council is now pleased to announce that they will be retransferred for that sum, together with any further indispensable outlay, to any parties who may establish satisfactorily that they are in the possession of sufficient skill and resources, and *boná fide* prepared to carry on the manufacture of iron and steel upon a scale commensurate to the probable needs of that portion of British India which is within reasonable distance of the works. His Excellency in Council will further be prepared to enter into an engagement, if so desired, to take annually for ten years, at fixed prices to be previously agreed upon, not less than a certain weight of the Company's manufactures. This weight will be determined with reference to the average requirements of the Government for railways and other public works in the territory to the north and east of the East Indian Railway from Calcutta to Mogal Serai. With a view to facilitate the formation of a judgment on the prospects of the enterprise, the reports by Ritter C. von Schwarz, which are specified in the heading to this Resolution, will be made public, and further explanations or information will, as far as practicable, be afforded; but it must be distinctly understood that the Government decline to be responsible for the accuracy of any calculations or estimates so put forward.

7. In order to ascertain more fully the capabilities of the Chanda district of the Central Provinces, Ritter C. von Schwarz was some months ago deputed to the locality, and has submitted a very full and able report, which is also now made public, under a similar reservation. The Government of India are now engaged in ascertaining the probable demand for iron and steel within a suitable radius of Chanda and in comparing the merits of that locality with those of others in the Central Provinces. Any infor-

mation which may become available will be published in due course. Similar investigations will be pursued in the Punjab and other parts of India, as circumstances may permit.

8. In view of the importance of fully developing at the earliest possible date the resources of India in coal and iron, and of the necessity of unity and vigour of action to this end, His Excellency the Governor General in Council is pleased to direct that the Department of Public Works of the Government of India shall be the initiating Department in relation to the utilization of these minerals, subject to the customary general control of the Department of Finance and Commerce in matters of contract and expenditure, and to the usual consultation of the Revenue or Political Department on any matters in which they may be respectively concerned. Those Departments, on the other hand, as also all Local Governments and Administrations, should, by the collection of information or otherwise, co-operate with the Department of Public Works towards the attainment of the end in view.

ORDERED, that this Resolution be communicated to all Local Governments and Administrations, and to the Public Works, Revenue and Agricultural, and the Political Departments of the Government of India; and that it be published, together with the reports of Ritter C. von Schwarz, in the *Gazette of India.*

Report on the reopening of the Bengal Iron Works for the production of 80 *tons castings per* 24 *hours.*

When, in 1875, the Bengal Iron Works Company first opened, English pig iron was selling in Calcutta at Rs. 60 per ton, whilst the cost of production of the pig iron made at the Company's Works was Rs. 65. Within two years this was reduced to Rs. 40, but meanwhile, or at least by 1878, English pig iron was quoted in Calcutta at Rs. 29 per ton. The Company being unable to further force down the cost price of their pig iron, the failure of the undertaking became manifest, and resulted in the closing of the Works in 1879. At this present time English pig iron of the quality which used to be produced at the Bengal Iron Works is selling in Calcutta at Rs. 35 per ton; therefore still Rs. 5 below the cost price arrived at by the Company.

As since the closing of the Works the prices of the raw materials (iron ores, coal and limestone) have not fallen, and as, on the other hand, the cost of labor has risen, the success of the reopening of the Bengal Iron Works depends on decreasing the cost of production through improved arrangements in some directions and a simplification of working procedure in others. To arrive at the desired result the following measures are proposed :—

1.—The substitution of certain machinery for certain manual labor formerly employed, and the introduction of certain simplified yet improved methods of working, both having for their object a saving of material and cost of labor.

2.—Arrangements for increasing the capabilities of the Works for the quantity of production by means of which, in an indirect way, the cost of labor, of management, wear and tear, &c., is diminished as the expenses on these are distributed over a larger amount of produce.

3.—Arrangements for utilizing the collateral produce of the Works.

In the following pages the proposed improvements will be treated of, namely, what they consist, and how in the present case they can be introduced expeditiously, cheaply and effectively.

It is evident that, in the main, the present arrangements will be maintained as much as possible, and that our task will consist more in completing these than in carrying out essential alterations.

I.—*Alterations in the blast furnaces.*

1. The height of each blast furnace and their hoist is to be increased by 6 feet, *viz.*, making their total height from bottom to top 61 instead of 55 feet, and the inner diameter of the furnace hearth to be increased from 5 feet to 6 feet.

2. The total square section of the nozzles should be raised from 20 to 35 square inches, the wind pressure from 5 to 8 inches mercury, and the number of the twyers should be doubled, *viz.*, the 3, as at present, should be increased to 6.

These alterations will increase the productive capacity of the furnaces which in general depends on the dimensions of the furnaces.

Next to the dimensions of the furnace it is the square section of the nozzles, the wind pressure, and the temperature of the same which, when raised, increase the productive capacity of the blast furnace ; nevertheless these must remain in a certain ratio to one another, and must be kept within certain limits dependent on the inner dimensions of the furnace.

The doubling of the twyers has for its object a more effective distribution of the wind, which becomes more necessary as the square section of the furnace, before the twyers, is to be enlarged.

3. The water twyers should be made of bronze instead of cast iron (as at present), water boxes for cooling the hearth should be introduced, the angle of inclination of the boshes should be enlarged to 80°, and the inner form of the furnaces rounded off, so as to avoid all sharp angles and sudden transitions in order to secure a uniform descent of the melting column, and to avoid a derangement of function through a blocking up of the melting column.

It may be mentioned here that the blast furnace No. 1 of the Bengal Iron Works, although its inner dimensions had been theoretically correctly chosen, was within scarcely two years so much burned away inside, and got so much out of shape, that it had to be laid cold, which drawback was caused by nothing else than the sharp transitions between shaft and boshes, the steep angle of inclination of the boshes, and the total absence of water cooling of the hearth.

Blast furnaces of a correct inner form should work at least from 8 to 10 years without any appreciable interruption.

The object of using bronze instead of cast iron for the water twyers is to achieve greater durability of the same, which, as experience has shown, is in this case of special importance, as through faulty twyers water enters the blast furnace, which, it is well known, deranges its function, and may even cause dangerous explosions.

Besides, the bronze twyers, when used up, have still the value of their metal, whilst old cast iron twyers are of little value as material.

4. It is further recommended to introduce, in connection with the blast furnaces, Leirmann's arrangement for drawing off the slags, instead of the obsolete system employed in the Bengal Iron Works to allow the slags to flow over the dam plate by means of the cinder notch. It would lead me too far to set forth all the advantages of this system ; a full description of it may be seen in the technical works of Dr. John Percy, Dr. Wedding and others. Suffice it to say that this system may be seen already in use in most blast furnaces of England, Germany and America.

5. The adoption is recommended of "Parry's cup and cone" for the furnace top and of all other arrangements for collecting, cleaning and conducting the blast furnace gases to the hot blast ovens and steam-boilers. "Parry's cup and cone" serves for closing the furnace top for the purpose of drawing off the gases, and at the same time also to facilitate an uniform and correct serving of the blast furnace with the raw materials, namely, iron ore, coke and lime-stone.

The apparatus combines simplicity with usefulness, and has also the advantage over all other apparatus of the same kind, that it renders possible so to serve the blast furnace that the workmen are in no way oppressed either by heat, dust, or by the poisonous gases always given off by the blast furnace when under serving.

Parry's cup and cone was first applied to a blast furnace at Ebbev Vale in South Wales, and has thence successfully spread to England, Germany and America.

In connection with Parry's cup and cone an arrangement is proposed for leading off and cleansing the blast furnace gases from dust, consisting of sheet iron pipes, in which at the bends dusting chambers are inserted.

The action of the dusting chambers is to suddenly increase the section of the gas conduit, whereby the velocity of the gases is reduced and the opportunity is given to the impurities to settle or precipitate themselves.

The most suitable form of this arrangement is the so-called "S apparatus." It is made of sheet-iron rivetted so as to be air-tight.

The bottom in one part does not join the sides (*vide* sketch in the margin), but is bent in a slanting form so that a connection exists between the inner space and the outside air in the manner of the communicating tube.

The lower part of the apparatus is filled with water, which serves as a separation between the gas and the atmosphere. The here precipitated dust of the gases may from time to time be removed with a shovel through the opening C.

The water serves at the same time as a safety valve, as, in case of too high a pressure in the gas pipe, it is forced out.

This cleansing apparatus has been successfully applied to all the new blast furnaces in the east of France, and has already been copied in Germany, England and Austria.

The apparatus for burning the gases have to be applied separately to each furnace and each boiler.

Their arrangement aims chiefly at mixing thoroughly the furnace gases with the air necessary for burning them, and to conduct this mixture over a lighting fire, in order that the gases may be kept constantly burning, and the danger of their being extinguished be prevented, as in this case an explosive mixture of air and gases would be evolved.

Blast furnace gases consist chiefly of carbonic oxygen gas (C. O.) (*vide* "Report on the Bengal Iron Works," page 2), which, to reach the desired effect, has to be completely burnt to carbonic acid (C. O. 2).

An arrangement answering the foregoing requirements may be seen in several new iron-works in England and Germany. It was first introduced in Neustads in Hanover, and is constructed on a principle of Faher du Faur.

6. It is also recommended to connect with each blast furnace a reserve apparatus for heating the wind (*vide* "Report on the Bengal Iron Works, page, 3").

7. It is further advised to introduce apparatus for utilizing the blast furnace slags in the fabrication of cement, artificial stones and "slag wool." (For particulars on this subject please see "Report on the Bengal Iron Works," page 2.)

II.—Apparatus required for preparing the raw materials.

1. Three ore crushers for the mechanical breaking up of the iron ore and limestone. (For particulars please see "Report on the Bengal Iron Works," pages 2 and 3.)

(2) Belgian cake ovens with a coal-washing apparatus.

The Burrakur coal has the following chemical composition :—

Fixed carbon.	65	per cent.
Carbon combined on hydrogen	6·60	"
Hydrogen	4·94	"
Oxygen and nitrogen	9·32	"
Sulphur	0·44	"
Moisture	3·65	"
Ashes	10·05	"

This coal with so high component parts of carbon and hydrogen, although its percentage of ashes is rather high, must be considered as well suitable for metallurgical purposes.

The coke made of this coal at the local coal mines has 16 to 18 per cent of ashes, and sells at more than double the price of the coal from which it is made.

Although the contents of fixed carbon in this coal is 65 per cent, and that of ashes 10·05 per cent (therefore the percentage of unvolatile matter is about 75), the coke produced from it is only 50 per cent; this shortcoming being due not to the quality of the coal, but to the primitive arrangement for making the coke. The arrangement consists in open kilns where the access of atmospheric air is not to be despised; but, on the other hand, under such conditions a considerable portion of the fixed carbon, the most valuable component of the coal in regard to the production of coke, is driven off along with other volatile substances as carbonic oxygen gas (C. O.); the outturn of coke is therefore poor, and the

quantity of ashes considerably increased. It may here be observed that a large proportion of ashes in coke reduces its value very much, for purposes of its use in the blast furnace: ashes consist chiefly of silicic acid (Si. O. 2) which, being almost infusible, requires a larger addition of limestone to melt it, and as a matter of course occasions a greater consumption of fuel. Besides, with coke rich in ashes a smaller quantity of carbon is distributed through a larger volume of matter, whereby the pyrometric effect of every description of fuel is diminished. In the Bengal Iron Works the production of one ton pig iron used to require the consumption of 36 cwt. of coke and 32 cwt. of limestone—a very unfavorable condition of working; it will therefore be necessary to introduce a more favorable system of coke-making, namely, first to wash the coal, that is, to free it as much as possible from the substances producing the ashes, and then to "distil" it in closed furnaces.

For the treatment of coal in making coke the Belgian coke furnaces (system Francois and Rexroth) would give in one case the best results.

These furnaces yield 95 per cent of the non-volatile components of the coal, and they are particularly suitable for India on climatic grounds, as the coke is removed from the furnace by a machine, by which the workmen are spared the enormous radiating heat. There is also a saving of coke through the quickness of the operation of removing it, as under a slow process some of it is lost by combustion.

These coke furnaces require no special firing; they heat themselves with their own gases, which are led in channels around them, and having done their duty to the furnaces, they are collected into a common channel, say for 25 furnaces one, and are then utilized for heating steam boilers.

With this system of furnaces the Burrakur coal may be made to yield coke containing from 6 to 8 per cent ashes only instead of 16 to 18 per cent as now, which would raise its value as a fuel for the blast furnace by 20 per cent, and the consumption of coke per ton of pig iron would be reduced from 36 to 28 cwt.

It should also be mentioned that the refuse of coal in the washing basins, a sort of coal mud, may be utilized for heating the drying furnaces in the foundry and for other subordinate heating purposes. (Please see "Report on the Bengal Iron Works," page 3, drying furnaces.)

III.—Blowing engine.

1. It is recommended that a second blowing engine of the capacity of the present be acquired. The amount of wind which must be forced into a blast furnace depends on the quantity of coke which is burnt in it in a given time, and upon the percentage of carbon in this coke.

It must here be remembered that the whole of the carbon in the coke must be reduced to carbonic acid (C. O. 2) to produce the desired effect in the blast furnace.

The present blowing engine may be estimated at a maximum effect of 5,980 cubic feet air per minute, but this is only half the requirement, which can be shown to be 11,344 cubic feet per minute; therefore, if the two blast furnaces are to turn out 80 tons of pig iron per 24 hours, a second blowing engine of the same effect as the present one is requred. The calculations to the above will be found in Appendix No. 1 (page 31).

2. The steam boiler establishment belonging to the blowing engines also will have to be proportionally increased to 440 horse-power, as the present one is only sufficient to yield 100 horse-power. For calculations please see Appendix No. 2 (page 33).

It must be mentioned here that the Bengal Iron Works Company never worked the two blast furnaces at the same time, which is chiefly due to the insufficiency of their boiler establishment being only able to furnish the motive power for the production of 20 tons of pig iron per 24 hours, although the blowing engine, blast furnaces, and hoist, chimney, &c., are corresponding to 40 tons production per 24 hours.

3. With the employment of a second blowing engine the dimensions of the blast conduit and regulator of blast will have also to be proportionally enlarged.

IV.—Storeyard for iron ore, limestone and fuel.

To keep up a sufficient stock of the raw materials in a proper way a better arrangement for their deposit is required. How this is to be managed may be seen from the annexed plan No. 1 (*vide* mixing plans and filling bank).

Under the circumstances before us a large stock of the raw materials is not required, as they are to be had in the immediate neighbourhood of the iron works, and there is no fear of interruption in their regular delivery. Without regard to the dead capital lying on large stores, there is a difficulty in controlling them ; they take up a large space, and cause other inconveniences.

As regards iron ores and limestone, a store for three months is ample. Of coal not more than a monthly store should be kept, as coal loses through long exposure to the air greatly in its value in consequence of the evaporations of the valuable carburetted hydrogen gases, especially during the dry season.

V.—Alterations on the foundries.

1. It has already been pointed out in my "Report on the Bengal Iron Works" (page 3) that the casting direct from the blast furnace, namely, without remelting the pigiron in the cupola furnace, is recommended.

To attain this it is advisable to remove the standing foundry No. I close to the blast furnaces (*vide* plan No. 1). This can be easily done, as the foundry shop mentioned only consists of a roof of corrugated sheet iron, supported by pillars and rolled beams. Most of the pillars are of wood, and should be replaced by cast iron pillars. As, however, the foundry shop No. I alone would not be sufficiently large for the production of 80 tons sleepers per day, and the foundry No. II being built of stone cannot be removed, the enlargement of foundry No. I and the erection of a new one (*vide* plan No. 1) will become necessary.

2. The foundry shop No. II can be especially arranged for making pipes ; the necessary alterations in the drying furnaces and the other arrangement for casting and tiering pipes have already been treated off in my "Report on the Bengal Iron Works" (pages 3 and 4).

3. The cupola furnaces attached to the foundry remain as a reserve in order to remelt the pig iron produced from the blast furnaces on Sundays and holidays (as the working of the blast furnaces cannot be stopped on such days), and to utilize the scraps of the foundries.

A slight alteration in their construction is recommended according to a principle invented by Fauler in Freyburg (Bavaria) ; to explain this invention in detail would lead too far, suffice it to say (*a*) that it has proved practicable since the last 5 years ; (*b*) that its virtues lie in the saving of 15 per cent of fuel ; and (*c*) that it can be cheaply introduced in the present arrangement of the cupola furnaces.

4. It is further recommended to use moulding machines for making sleepers.

These machines serve to lift the pattern out of the sand *strictly vertical*, which can never be correctly accomplished by hand, in consequence of which much labor and time is lost in repairing the mould.

These machines are especially adapted where many castings of *one* pattern are required, which is therefore suitable in our case.

5. The introduction of an apparatus to gain the "wash iron" out of the used sand of the foundry and the pig bed shed of the blast furnaces is advised.

This apparatus is an inexpensive arrangement, by which the greater part of the spilled cast iron can be regained ; it renders 2 per cent of the production of castings, namely, about 1½ tons "wash iron" per diem.

VI.—Alteration in the chief water-supply.

In consequence of the proposed enlargement of the foundry and the blast furnaces, the cooling apparatus for the latter, and the erection of coke furnaces, &c., the present arrangement for water-supply will not be sufficient. Besides this, the present way of supplying water is so complicated a one that it can bear being simplified by this opportunity. It consists now in pumping out the water from the Barakar river by means of a large pumping engine erected on its banks, and leading it through cast-iron pipes of 10 inch diameter for a distance of about 1¾ miles to a tank near the iron works : from there the water is pumped up to a height of about 10 feet into a second smaller tank, from whence it is led by means of pipes to wells situated near the blast furnaces and the foundries ; here it is pumped for the *third* and last time into the highwater reservoirs, from whence at length it is led to its destination. To

avoid this roundabout way it is recommended to erect a highwater reservoir, for about 15,000 cubic feet contents, on the border of the large tank, and to lead it from thence directly to its destination.

As the required quantity of water is rather large, and the difference between the water levels of the tank (from where the water is to be pumped *out*) and the highwater reservoir (where it is to be pumped *in*) will be not more than about 30 feet, *centrifugal pumps* are recommended.

VII.—Buildings and out-houses.

1. The greater part of the out-houses belonging to the works were built of mud walls with thatched roofs, and are now in a tumble-down condition, leaving only the stones lying about, which will do for rebuilding them.

2. For native workmen it is recommended to make a bathing tank, which can be easily done by enlarging the present one.

3. The erection of huts for about 600 coolies is also advised.

4. A boundary wall round the works should also be erected in a substantial way so that it answers the purpose. Although it is rather expensive, most of the iron works are provided with one, as the damage caused by running away of workmen, unbidden visitors, and stealing, justifies the greater expense of a wall.

This wall must be about 7½ feet high, and must be provided with sharp objects (the simplest ones being blast furnace slags) built in on the top in order to prevent the scaling of the wall.

VIII.—European workmen.

With regard to European workmen for iron working in general, I refer to the "labor question" treated of in my Report on Chanda (page 10).

To start the works, in order to produce 80 tons castings per 24 hours, the following European working have to be brought out from Europe :—

(1) One blast furnace foreman.
(2) Four first men for the blast furnaces.
(3) Four second men for ditto.
(4) Four third men for ditto.
(5) Two workmen for the coke furnaces.

IX.—Amount of production.

The cast-iron parts for one sleeper (broad-gauge railway) weigh, including jaws, about 188 lbs. ; the sleepers lie at a distance of one yard, centre to centre from each other ; this gives a consumption of 148 tons of cast iron per running mile railway.

Therefore, with the proposed arrangements (which allow the production of about 80 tons of sleepers per 24 hours) it would be possible to yield the requirement of *sleepers for about half a mile of railway per day.*

Approximate estimate

for the improvements and repairs of the Bengal Iron Works for the production of 80 tons of cast-iron sleepers and other castings per 24 hours (*vide* plan No. 1).

I.—Furnaces and Machinery.

(*a*)—*For the blast furnaces*—

	Rs.
3 ore crushers	7,200
Derrick and steam engine for the same	2,500
Raising of the blast furnaces and their hoist by 6 feet and repairs on the casing of the furnaces	14,000
"Parry's cap and cone" on each blast furnace	2,500
Twyers, nozzles, water-boxes, damplates, and other cast and wrought-iron parts for the furnaces	3,500

	Rs.
Apparatus for catching, purifying and distributing the blast furnace gases to hot blast ovens and steam boilers	25,000
New inside lining for the two blast furnaces	3,500
Two new hot blast ovens	8,000
Ten new steam boilers ... ... Rs. 45,000 / Masonry mountings ... ... " 15,000 }	60,000
Repairs on the standing steam boilers and hot blast ovens	7,000
Increasing of the wind conduit, regulator of blast, steam and water-pipes, &c. ...	10,000
One new blowing engine with two water-pumps, including foundations ...	40,000
Cinder and ore tubs, scales, tools, &c.	14,000
Apparatus for the gaining of "wash iron"	3,000
(b)—For the coke furnace—	
Coal-washing apparatus, including steam engine, washing basins, &c.... ...	35,000
50 Belgian coke furnaces for the production of 120 tons coke per 24 hours, including steam engine, tools, &c.	72,000
(c)—For the foundries—	
15 moulding machines for cast-iron sleepers...	15,000
Changes on the cupola furnaces, and providing them with water-cask elevators ..	2,500
Alteration in the arrangement for casting and tiering pipes	7,500
Moulding boxes, patterns, ladles, tools, &c.	10,000
About 2,000 running feet small railway, including turntables	4,500
Repairs on the standing machinery and shifting of the principal railway ...	4,000
(d)—For the water-supply—	
One highwater reservoir on the banks of the water tank for 15,000 cubic feet contents	8,000
Two centrifugal pumps, including steam engine transmissions and fittings of the reservoir	4,500

II.—Buildings and Earthworks.

(a)—For the blast furnaces—	
Ore-crush house	5,000
New mixing place and filling banks	18,000
One blowing-engine house	7,500
One new chimney, 120 feet high	4,000
Repairs on the standing chimney and providing it with iron anchorage ...	1,000
Two slag wool houses	1,000
(b)—Coke furnaces.	
Building and chimney for the coal-washing machinery	7,500
(c)—For the foundries.	
Transport and increase of the standing foundry shop No. 1 and replacement of the wooden by cast-iron pillars	9,400
Erection of a new foundry hall close to the blast furnaces	24,500
(d)—Out-houses.	
Repairs on the standing out-houses and furniture for office and dwelling houses for European workmen	15,000
One large bathing tank for native workmen...	2,000
Native huts for about 600 coolies	6,000
Boundary wall	8,000

III.—Working Capital.

Amount invested in stores	70,000
Reserve funds	1,00,000
IV, Engagement and bringing out of 16 Europeans ...	8,000
Total Rs.	6,50,200

Recapitulation.

	Rs.
Cost of Furnaces and Machinery	3,63,200
„ of Buildings and Earthwork	1,09,000
Working Capital	1,70,000
Engagement and bringing out of 16 European workmen	8,000
Total Rs.	6,50,200

APPROXIMATE COST OF PRODUCTION.

1—*Cost of one ton grey pig iron.*

1·95 tons iron ore at 12 annas per ton	1·46
1·40 „ coke at Rs. 8 per ton	11·20
1·10 „ limestone at Rs. 4 per ton	4·40
Wages	3·94
Management, wear and tear, &c.	7·00
Total Rs.	28·00

2—*Cost of one ton cast-iron sleepers, cast directly from the blast furnace.*

1·05 tons grey pig iron at Rs. 28	Rs.	29·40
0·40 tons coal for heating boilers at Rs 2½	„	1·00
Wages	„	12·60
Management, wear and tear, &c.	„	4·00
Total Rs.		47·00

3—*Cost of one ton cast-iron pipes cast from the cupola furnaces.*

1·08 grey pig iron at Rs. 28	Rs.	30·24
0·40 tons coal at Rs. 2·5	„	1·00
0·10 „ coke at Rs. 8	„	0·80
Wages	„	16·46
Management, wear and tear, &c.	„	5·50
Total Rs.		54·00

REMARKS.—In the calculation of the costs of production, the *actual* expenses are only taken into account *excluding* interest of capital invested in one iron work.

2. The prices are given in rupees, per ton, at the works.

Comparative Statement showing the difference of prices of cast iron goods in different Railway Stations.

Names of Stations.	Cast-iron Railway Sleepers.			Cast-iron Pipes.		
	English prices.	Our cost prices.	Difference in our favor.	English prices.	Our cost prices.	Difference in our favor.
Howrah	59·0	53·7	5·3	80·0	60·7	19·3
Barakar	65·7	47·0	18·7	86·7	54·0	32·7
Dinapore	75·7	57·0	18·7	96·7	64·0	32·7
Agra	98·0	80·0	18·0	117·0	87·0	30·0
Gwalior	107·0	89·0	18·0	126·0	96·0	30·0
Lahore	117·0	99·5	18·0	136·5	106·5	30·0
Mooltan	127·0	109·0	18·0	146·0	116·0	30·0

REMARKS.—The prices are given in rupees per ton, including freight; the latter is calculated at the rates for first class railway goods.

APPENDICES.

Appendix No. 1. The quantity of air required per minute is calculated by the equation :

$$Q = 1{\cdot}1\ A.\ P. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad \text{No. 1.}$$

where Q is the quantity of air in cubic feet to be introduced in the blast furnaces per minute ;
A is the consumption of coke per 24 hours expressed in tons ;
P is the proportion of carbon in the coke.

If, as proposed, Belgian furnaces with washing apparatus will be used for the manufacture of coke from the Barakar coal, the proportion of carbon in the coke will be $P = 92$, and the consumption of coke per 24 hours will be $A = 112$ tons, the outturn of pig iron with this fuel by the two blast furnaces being assumed at 80 tons per 24 hours.

By substituting these values in equation No. 1, we get $Q = 1{\cdot}1 \times 112 \times 92 = 11{\cdot}344$ *cubic feet of air* required per minute for both blast furnaces together.

The effect of the present blowing engine in the Bengal Iron Works is calculated by the equation :

$$9' = \infty\ .\ f.\ v.\ n, \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad \text{No. 2.}$$

where $9'$ is the quantity of air in cubic feet which can be delivered by the blowing engine per minute ;
f the inner section of each cylinder in square feet : in the present instance $f = 23$;
v the speed of the piston in feet per minute, the maximum in the present instance being assumed at 200.

n, the number of cylinders : in the present instance $n = 2$; and

∞, the working effect of the blowing engine inclusive wind conduit, which may be assumed to be in this case 0·65, namely 35 per cent of the theoretical effect being lost through leakage in the wind conductors, especially in the hot blast ovens.

Substituting these values in equation No. 2, we get the maximum effect of the present blowing engine $9' = 0{\cdot}65 \times 23 \times 200 \times 2 = 5{,}980$ cubic feet per minute, that is to say, about half of what is required, which, as found before, is 11,344 *cubic feet* per minute.

Appendix No. II—The necessary motive power for the two blowing engines is calculated by the equation :

$$N. = \frac{1}{G\infty} \times 0{\cdot}0045\ P.\ Q. \ldots\ldots\ldots\ldots\ldots\ldots \text{No. 3.}$$

where N is the requisite number of horse powers to drive the two blowing engines ;
G. the working effect of the steam engine, in our case 0·75 per cent ;
∞. the working effect of the blowing engines and wind conduit ; as before 0·65 per cent ;
P. the pressure of the wind on the nozzles ; in our case $P = 4$ *lbs.* per square inch ; and
Q. the quantity of air and cubic feet per minute, as previously calculated = 11,344.

These values substituted in equation No. 3 we get :—

$$N. = \frac{1}{0{\cdot}75 \times 0{\cdot}65} \times 0{\cdot}0045 \times 4 \times 11{,}344 = 120{\cdot}5$$ *horse power*, being the requisite motive power for the two blowing engines.

Besides the blowing engines there is required the necessary motive power for driving the [illegible] and the feeding pumps for the boilers, which [illegible] about 20 horse power ; therefore altogether a steam boiler establishment of 440 horse power will be required to serve the whole machinery belonging to the blast furnaces.

The standing steam boiler establishment consists of 7 "egg-ended boilers," each of which having a total length of 28 feet and 5 feet diameter, representing a "fire surface"—(the part of the boilers in contact with the fire) of 230 square feet per boiler.

Considering the construction of these boilers a "fire surface" of 16 square feet can be calculated for each horse power ; therefore a real effect of about 100 *horse power* can be furnished by the seven standing boilers together ($\frac{230 \times 7}{16} = 100$).

But as this motive power answers only for the production of 20 tons pig iron per 24 hours, the erection of a second steam boiler establishment is required to furnish the necessary effect of 440 horse power.

It must be observed that two steam boilers must be kept as a reserve in case those in use require cleaning or repairing.

BURRAKUR ;
The 16*th June* 1882.

(Sd.) R. C. VON SCHWARZ.

The manufacture of wrought iron and steel at the Bengal Iron Works.

For the manufacture of wrought iron and steel, and especially for the production of rails, beams, girder, and ship plates, &c., on a large scale, the introduction of the *basic* Bessemer process is recommended. With this process the contents of phosphorus in the pig iron (produced from the Barakar iron ores) can be reduced from 1·36 to 0·04 per cent, and therefore a quality of wrought iron and steel produced, which is suitable for the production of steel rails, rolled beams, &c. (An analysis of the pig iron produced by the Bengal Iron Work Company is shown in my report on the Bengal Iron Works, page 3).

The Spiegeleisen (specular pig iron) for the production of steel in the Bengal converter cannot be obtained from the Barakar iron ores on account of their qualities and their [illegible] contents of manganese. "Spiegeleisen" has therefore to be imported.

It is of great importance in the *basic* Bessemer process to procure a suitable basic fireproof material for the inner lining of the converter, as imperfect material for this purpose would cause costly interruption of the work by the wearing out of the lining too quickly. Besides, the making of basic fire bricks is very expensive, and the renewing or repairing of the inner lining of the Bessemer converter is a disagreeable and tedious labor, as the workmen have to suffer great heat and the work has to be done carefully and exactly.

Dolomite (magnesium limestone) has proved the best material in practice for the purpose, and such is to be found near Ramlallpur, about 7 miles south of Raneegunge, and near Purda (Lat. 22° 59′ 15″; Long 86° 37′ 45″). Dolomite of an excellent quality also occurs in the stream beds near Darjeeling, where it is rolled down from a range of hills composed of dolomite, which occurs just beyond the British boundary in Bhootan; the same rock also occurs east of P[illegible] in British territory (Mem. G. S. T., Vol. XI, page 83).

The following is an analysis of this dolomite :—

Carbonate of lime (Co. O. Co 2)	60·5
Ditto „ magnesia (Mg. O. Co 2)	38·7
	0·3
	99·5

Although this dolomite will be rather expensive to procure, it may pay to use it for the converter lining for the reasons explained. The pig iron has to be re-melted in cupola furnaces, as it is not sufficiently pure and regular for this process to be led directly in a liquid state from the blast furnaces into the converter.

Amount of Production.

It is a general rule to produce as large a quantity as possible in a rails rolling mill in order to distribute the high expenses for workmen and establishment, combined with such an undertaking over a great amount of production.

As we are not depending here on vegetable fuel but all raw materials are to be had in unlimited quantities, it is the manual aptitude and practice of the workmen serving the rolling mill and the converting department which furnishes the basis for the quantity of production. In England and America the most astonishing results in this direction have been attained; the average outturn of a *single* rails rolling mill is there 410 tons of finished rails per 24 hours, but exceptionally also 600 tons have been turned out in the same time when making "double headers" of 80 lbs. per yard.

It is very doubtful whether such results can be attained here, therefore the annexed calculations of the cost of production are, for security, based on a production of 200 tons of finished rails per 24 hours.

It must be mentioned that in a rails rolling mill also rolled beams, rolled sleepers, girder and ship plates and other rolled iron or steel goods of the stronger kind can be produced if the necessary cylinders (rollers) are provided.

To provide the necessary pig iron for the production of 200 tons of finished rails per diem, it is not advisable to use the existing blast furnace establishment, this being only constructed for a production of 40 tons per diem, for both blast furnaces, whilst about 200 tons of pig iron are wanted.

These blast furnaces should be put in thorough order for making pig iron for castings only, for which purpose they were originally built. For the production of the pig iron for the rolling mill it is recommended to erect a new blast furnace establishment consisting of two blast furnaces on the declivity of a

small hill, which is at a distance of about 1,000 yards from the existing establishment. The railway siding can be prolonged up hill to a length of about 1,000 yards, rising to a maximum height of 50 feet in order to form a viaduct from which the raw materials can be thrown over for the purpose of concentrating the stock in a comparatively small space (*vide* Report on the Bengal Iron Works, page 1).

Each of these new blast furnaces can be constructed for an outturn of 100 tons of pig iron per 24 hours, giving at the same time better results than the existing blast furnaces would yield with regard to the consumption of fuel and cost of labour, management, wear and tear, &c., for well known reasons.

This establishment should be constructed in such a manner that an increase of it by a third or fourth blast furnace could be accomplished (if the requirements of the rails rolling mill should be augmented) without interfering with the original system and without disturbance to the work of the existing establishment.

The scraps of the rails yield a suitable material for the manufacture of wire as is done in Cleveland: a Bessemer establishment producing daily 200 tons of rails can in this wise turn out 20 to 25 tons of wire in the same time.

The slag of the basic Bessemer process, owing to its contents of phosphate of lime, can be used as manure, as is the practice in Germany.

The puddling and welding process.

For the production of bar-hoop and facon iron of the smaller kind the introduction of the puddling and welding process is recommended. The contents of phosphorus in the pig iron can be reduced in the puddling furnace from 1·36 to 0·25 per cent, and thus renders a material suitable for the manufacture of bar iron of the so-called "refined" quality.

The existing blast furnaces can be arranged for the outturn of about 80 tons of white pig iron for 24 hours, which would yield the necessary material for the production of about 62 tons of small bar iron, facon iron, &c. It may be mentioned that for the production of small facon iron (double T. V. iron, bridge rails, &c.,) a small contents of phosphorus is necessary, in order to enable the iron to fill out the complicated shapes of the calibres of the rollers. The circumstances in our case are therefore especially adapted for this purpose.

Railways and Tramways.

As the iron ores of Burrakur are to be had in unlimited quantities in the immediate neighbourhood of the works, and as they can be obtained by simple surface digging, the erection of a tramway for their transport is not necessary; they can be cheaper transported by carts.

Limestone occurs in Pacheet and Hansapather, at a distance of about 8 and 10 miles from the works. For the making of 200 tons rails and 80 tons castings per diem (as proposed) about 320 tons of this limestone would be required daily. It is therefore advisable to construct a tramway for its transport.

This tramway, however, would have to cross the Damuda river, and this can be done by means of a "causeway," as a bridge over that river (at least for the present) would be too expensive.

The river can in this wise be crossed for 7½ months in the year, and a store of limestone for the remaining four and half months (during the rainy season) has to be kept at the works. The transport of coal to the works and that of finished goods from the works is managed by the East Indian Railway (Seetarampore-Burrakur Line), with which the works are connected by means of a siding.

APPROXIMATE COST OF PRODUCTION.

(1) Cost of one ton grey pig iron for the Bessemer process—

	Rs.
1·95 tons iron ore at 12 annas per ton	1·46
* 1·20 tons coke at Rs. 8 per ton	9·60
1·10 tons limestone at Rs. 4 per ton	4·40
* Wages	3·54
* Management, wear and tear, &c.	6·00
Total...	25·00

* The consumption of a coke in a blast furnace per one ton of pig iron is smaller when the production in a given time is greater; also the expenses for wages, management, and wear and tear diminish with the increase of production.

(2) Cost of one ton Bessemer steel rails—

	Rs.
1·22 tons grey pig iron at Rs. 25	30·50
0·06 tons Spiegelesen iron at Rs. 120...	7·20
0·12 tons coke at Rs. 8	0·96
1·20 tons coal iron at Rs. 3	3·60
0·20 tons burnt lime at Rs. 8	1·60
Wages	9·64
Management, wear and tear, &c.	9·50
Total...	63·00

(3) Cost of one ton Bessemer iron rails—

	Rs.
1·28 tons grey pig iron at Rs. 25	32·00
0·12 tons coke at Rs. 8	0·96
1·20 tons coal at Rs. 3	3·60
0·25 tons burnt lime at Rs. 8	2·00
Wages	9·34
Management, wear and tear, &c.	9·10
Total...	57·00

(4) Cost of one ton white pig iron for the puddling process—

	Rs.
1·95 tons iron ore at 12 annas	1·46
1·05 tons coke at Rs. 8	8·40
1·10 tons limestone at Rs. 4	4·40
Wages	3·44
Management, wear and tear, &c.	6·30
Total...	24·00

(5) Cost of one ton puddled bar and facon iron—

	Rs.
1·25 tons white pig iron at Rs. 24	33·00
2·50 tons coal at Rs. 3	7·50
Wages	11·70
Management, wear and tear, &c.	12·80
Total...	62·00 (?)

Comparative Statement showing the Difference of Prices of iron and steel goods in different Railway Stations.

Names of Stations.	Bessemer Steel Rails.			Bessemer Iron Rails.			Puddled Bar Iron "Refined."		
	English prices.	Our cost prices.	Difference in our favour.	English prices.	Our cost prices.	Difference in our favour.	English prices.	Our cost prices.	Difference in our favour.
Howrah	85·0	69·7	15·3	70·0	63·7	6·3	115·0	68·7	46·3
Burrakur	91·7	63·0	28·7	76·7	57·0	19·7	121·7	62·0	59·7
Dinapore	101·7	73·0	28·7	86·7	67·0	19·7	131·7	72·0	59·7
Agra	124·0	96·0	28·0	109·0	90·0	19·0	152·0	95·0	57·0
Gwalior	133·0	105·0	28·0	118·0	99·0	19·0	161·0	104·0	57·0
Lahore	143·5	115·5	28·0	128·5	109·5	19·0	171·5	114·5	57·0
Mooltan	153·0	125·0	28·0	138·0	119·0	19·0	181·0	124·0	57·0

Approximate Estimate of an iron work producing 200 tons Bessemer steel rails per diem (see plan No. III).

—Furnaces and machinery—

(*a*) For the blast furnaces—

	Rs.	Rs.
5 ore crushes	12,000	
2 blast furnaces, each producing 100 tons of pig iron per 24 hours, cast and wrought iron parts	1,30,000	
Masonry	30,000	
		1,60,000
1 hoist for iron ores, coke and limestone		25,000
2 blowing engines, each 12,500 cubic feet air per minute, with two water pumps—		
Machinery	1,20,000	
Foundation	20,000	
		1,40,000
6 large hot blast ovens cast wrought iron parts	30,000	
Masonry	10,000	
		40,000
Apparatus for catching, purifying and cleaning the blast furnace gases and distributing them to the steam boilers and hot blast ovens ...		40,000
Regulator of blast, blast main stream, and water-pipes		25,000
Steam boilers for 1,100 horse power boilers...	1,10,000	
Masonry and mounting	40,000	
		1,50,000
2 water reservoirs, each for 20,000 cubic feet contents		20,000
Chinder and ore tubs, scale, tools, &c.		20,000

(*b*) For the Bessemer and rolling mill—

	Rs.	Rs.
3 larger cupola furnaces (system Fauler) for re-melting the pig iron, including hydraulic lift—		
Cast and wrought iron parts	20,000	
Masonry	4,000	
		24,000
2 small cupola furnaces (for melting the "Spiegeleisen") including lift—		
Cast and wrought iron	5,000	
Masonry	1,500	
		6,500
2 Bessemer converters, each for 6 tons contents—		
Cast and wrought iron	18,000	
Masonry	4,000	
		22,000
3 drying furnaces with cranes :—		
Cast and wrought iron	2,500	
Masonry	2,000	
		4,500
6 gas furnaces for re-heating Bessemer Ingots and Blooms, including cranes, cast and wrought iron parts	30,000	
Masonry	11,000	
		41,000

	Rs.	Rs.
1 blowing engine for the Converting Department :—		
Machinery	36,000	
Foundations	6,000	
		42,000
1 hydraulic crane for 10 tons maximum weight :—		
Machinery	7,500	
Masonry	2,000	
		9,500
3 hydraulic cranes for 4 tons maximum weight :—		
Machinery	5,000	
Masonry	1,500	
		6,500
1 water pump with accumulator for the hydraulic machinery :—		
Machinery	10,000	
Masonry	3,000	
		13,000
1 blowing mill, with 250 horse-power steam engine and 45 tons fly wheel :—		
Machinery	70,000	
Masonry (foundation)	8,000	
		78,000
1 rails mill with 300 horse-power steam engine and 40 tons fly wheel :—		
Machinery	90,000	
Foundation	11,000	
		1,01,000
1 steam hammer for cutting Bessemer blooms, including crane :—		
Machinery	15,000	
Foundation	5,000	
		20,000
24 steam boilers, each for 30 horse-power :—		
Boilers	72,000	
Masonry and mountings	24,000	
		96,000
2 water reservoirs, each for 15,000 cubic feet		15,000
2 water pumps, including steam engine		6,000
3 steam boiler feeding pumps, including steam engines		4,800
1 large scale for weighing the Bessemer blocks :—		
Machinery	2,500	
Masonry	1,500	
		4,000
Rails finishing plant, circular saws, drilling, straightening and slotting engines, &c.		30,000
Cooling beds for rails		5,000
1 45 horse-power steam engine for the rails finishing plant —		
Machinery and transmissions	5,500	
Foundation	700	
		6,200
Steam, water and air pipes, and 2 root's blowers...		16,000
Fans, railways, wagons, ingots, moulds, scales, tools, &c.		14,000
1 large lathe for the cylinders		5,000
(c)—For the coke furnaces—		
2 coal-washing apparatus, including steam engines, disintegrators, basins, &c.		70,000
100 Belgian coke furnaces, including steam engine, tools, &c.		1,42,000

II.—Buildings—

(a).—For the blast furnaces—

	Rs.
Ore crush house	8,000
Mixing place and filling bank for ore, limestone and coke	30,000
2 blowing engine houses	24,000
Building for the hoist	12,000
Foundry hall	22,500
2 chimneys, each 120 feet high	8,000
Channels and drains	6,000

(b) For the Bessemer mill—

Bessemer and rolling mill	3,00,000
2 Chimneys, 120 feet high	8,000
Channels, drains, &c.	6,000

(c) For the coke furnaces—

Building and chimney for the coal-washing machinery	12,000

(d) Workshops and out-houses—

2 Blacksmith's shops with interior arrangements	25,000
Store rooms	12,000
Scale and porter house, including scale	5,000
Dwelling houses, barracks, offices, &c.	60,000
Native huts for about 1,000 coolies	10,000
Boundary wall	12,000

III.—Working Capital—

Amount invested in stores	1,50,000
Reserve funds	1,00,000

IV.—Earthwork—

Levelling, ditches, tanks, &c.	20,000

V.—Tramways and Railways—

10 running miles tramway for bringing the limestone, at Rs. 12,000 ...	1,20,000
Prolongation of the railway siding for 1,000 yards	50,000

VI.—Engagement and bringing out of 70 Europeans	35,000
Total	24,49,500

Recapitulation.

Cost of Furnaces and Machinery	14,14,000
„ Buildings and Earthworks	5,80,500
„ Tramways and Railways	1,70,000
„ bringing out Europeans	35,000
Working Capital	2,50,000
Total ...	24,49,500

An iron work producing daily 200 tons Bessemer steel rails costs Rs. 24,49,500.

Conclusion.

The local circumstances with regard to the quantity and quality of the raw materials at the Burrakur Iron Works are specially adopted for the production of rails, rolled beams, girder and ship-plates and other rolled goods of the stronger kind on a large scale, and for the production of ordinary castings, as railway sleepers, pipes, pillars, &c., as well as for the manufacture of bar and facon iron of "refined" quality. ...

The raw materials are to be had in unlimited quantities, and cheap enough to produce iron and steel goods of the above kind at competition and profitable prices, if the manufacture of them is conducted on modern principles.

With the proposed improvements and arrangements, namely,—

(1) putting the existing blast furnace establishment and foundries into thorough order for the production of castings,
(2) the erection of a new establishment for making rails, &c.,
the daily outturn of the whole work would be—
(1) 80 tons ordinary castings (principally railway sleepers) ; and
(2) 200 tons rails, beams and other rolled goods of the *stronger* kind.

The production of puddled bar and facon iron, if desired, could be begun on a much smaller scale than the production of rails, and would still pay : the two existing blast furnaces could be arranged—*one* for the production of *grey* pig iron for castings, and the *other* for the manufacture of *white* pig iron for the puddling process ; in this wise there could be turned out daily—

(*a*) 20 tons of ordinary castings, and
(*b*) 18 tons of bar and facon iron.

The cost of this arrangement would be about 5 lakhs of rupees in all. Owing to the geographical situation of the works, and considering the railway freight for iron goods, prevailing in India, the most profitable sale districts for iron and steel goods, made at Burrakur, would be Bengal, the North-Western Provinces and Oudh, and they could also be sold in Central India and Punjab at competition prices.

BURRAKUR ;
The 30th June 1882.

(Sd.) R. C. VON SCHWARZ

Approximate Estimate for the improvements and repairs of the Bengal Iron Works for the production of forty tons of cast iron sleepers and other castings per 24 hours (vide plan No. II).

I.—FURNACES AND MACHINERY.

(*a*)—*For the blast furnaces*—

		Rs.
Two ore crushes		4,800
Derrick and steam engine for the same		2,000
"Parry's cup and cone" for each blast furnace		2,500
Repairs on the casing of the blast furnace		3,000
Tuyers, nozzles, water-boxes, damplates and other cast and wrought iron parts for the blast furnace		2,500
Apparatus for catching, purifying and distributing the blast furnace gauges to the hot blast ovens and steam boilers		20,000
	Rs.	
New inside lining for the two blast furnaces...		3,500
One new hot blast—blast ovens		4,000
Four new steam boilers—boilers	18,000	
Masonry and mountings	6,000	24,000
		66,800
Repairs on the standing steam boilers and hot blast ovens		7,000
Increasing of the wind conduit, steam and water pipes		5,000
Cinder and ore tubs, scales, tools, &c.		10,000
Apparatus for making "wash iron"		3,000

(*b*)—*For the Coke Furnace*—

Coal washing apparatus, including steam boilers, steam engine, and washing basins...	25,000
Twenty-five coke furnaces for the production of 60 tons coke for 24 hours, including steam engine, &c.	42,000

(*c*)—*For the Foundries*—

Eight moulding machines for cast iron sleepers	8,000
Changes on the cupola furnaces and providing them with water cask elevators ...	2,500
Alteration in the arrangement for casting and tiering pipes	7,500

	Rs.
Moulding boxes, patterns, ladles, tools., &c.	7,000
About 500 feet small railway, including turntable	3,700
(d)—For the Water-supply—	
One high-water reservoir on the banks of the tank for 10,000 cubic feet water ...	6,000
Two centrifugal pumps (each 3″ diameter of delivery pipe) including steam engine transmissions and fittings for the reservoir	3,500

II.—BUILDINGS AND EARTHWORKS.

(a)—For the blast furnace—	
One crush house	4,000
Mixing place and filling bank	12,000
Anchorage and repairs on the chimney	1,000
Arrangement for making slagwool	1,000
(b)—Coke Furnace—	
Building and machinery for the coal washing machinery...	7,500
(c)—Foundries—	
Transport and increase of the foundry shop No. 1 and replacement of the wooden by cast iron pillars	9,400
(d)—Out-houses—	
Repairs on the standing out-houses and furniture for office and dwelling-houses for European workmen	15,000
One large bathing tank for native workmen...	2,000
Native huts for about 400 coolies	4,000
Boundary wall	8,000

III.—WORKING CAPITAL.

Amount invested in stores	40,000
Reserve funds	70,000
IV.—ENGAGEMENT AND BRINGING OUT OF 16 EUROPEANS ...	8,000
Total ...	3,78,400

Recapitulation.

Cost of furnaces and machinery	1,96,500
Cost of buildings and earthworks	63,900
Working capital and reserve funds	1,10,000
Cost of bringing out Europeans	8,000
Total ...	3,78,400

The 20th June 1882. (Sd.) R. C. VON SCHWARZ.

REPORT ON THE BENGAL IRON WORKS.

Parts of works.—The works consist essentially of two blast furnaces, each capable of producing 20 tons of grey pig iron for castings per 24 hours, and of a casting establishment of two separate buildings with all necessary machinery, finishing and repairing workshops; also of offices, store-rooms, scale-houses, water reservoirs, dwellings, &c.

Situation.—The situation of the works may be described in general to have been well chosen, as the principal raw materials, namely, the iron ores, coke and limestone, are found in the immediate neighbourhood and in sufficient quantities. It would, however, have been better if the works had been built on the Barrakur river, which is at a distance of about $1\frac{3}{4}$ miles, as the water required for them is not to be found in the present situation, but must be led to them from that river.

This shortcoming has rendered necessary the establishment of a special and expensive pumping engine with boilers, and a water conduit of about 8,500 feet in length, consisting of 10-inch cast iron pipes. This water conduit alone may have cost Rs. 50,000 which might have been saved if the works had been built immediately on the river.

Raw materials.—The *iron ores* are brown hematite, and consist of 47 per cent of metallic iron on an average, or 78 per cent of hydrate sesquioxide of iron ($2S^e_2 O_3$, 3 H O) : the impurities are 12 per cent silicic acid (S_i O_2) and 6 per cent aluminia (Al_2 , O_3), the rest being protoxide of manganese (M_n O), phosphoric acid (P O_5), and traces of sulphur. The iron ores are found close to the iron works and on the surface of the ground ; there is, therefore, no expensive mining arrangements necessary ; they can be delivered at the iron works for 12 annas per ton, inclusive of all costs.

The *coke* is made likewise near the works, as the coal mines are near. The coke is well burnt, but contains a good deal of ashes. It costs when delivered at the iron works from Rs. 8 to Rs. 10 per ton, according to quality.

The *limestone* is obtained from a distance of above 5 miles. It consists of 71⅓ per cent of cacium carbonate (C_a O C^o_2), 17 per cent other alkalies, and 11½ per cent silicic acid (S^i O_2). This limestone, on account of the heavy contents of silicic acid, cannot be considered very satisfactory for the blast-furnace process ; in fact, through the 12 per cent silicic acid in the ores the heavy percentage of ashes in the coke (consisting also chiefly of silicic acid) and the 11⅓ per cent of the same in the limestone itself, the consumption of limestone is so heavy that it reduces the value of the great contents of the iron in the ore.

In general, however, the above raw materials are good enough, and their prices so exceedingly low as to have justified the establishment of an iron work in that place for their utilization.

Blast furnaces.—The blast furnaces are on a well approved Scotch system, and the engines belonging to them, such as the blowing engine, hoist, water-pumps, &c., are well built and well preserved. There is, however, this shortcoming, that there is no suitable arrangement for concentrating the stock of the principal iron materials (ores, coke and limestone) in a comparatively small space. With the great quantities required of these materials, there should have been built behind the furnaces a viaduct, at least 45 feet high, on which to convey these materials and throw them over. With the present arrangement they are spread over a large space, which occasions a considerable expense for bringing them to the blast furnace, and other inconveniences.

Blowing engine.—The blowing engine is double cylindrical, vertical, of approved construction, and in good preservation. For the adjustment of the blast there is a small receiver.

Hoist.—The hoist for the ores, coke and limestone is a costly, well constructed machine, in good preservation, and is worked by a horizontal double-cylinder steam-engine. It may be observed that for this purpose a so-called "water cask elevator," of a very cheap construction, would have done as well. This arrangement has been introduced in many European iron works with success, where in winter time its working is not hindered by the formation of ice ; it is therefore suitable for India.

Steam-boilers and chimney.—For the working of the machinery of the blast furnace, there are seven cylindrical boilers, each about 26 feet long and 5½ feet in diameter ; these are all built in, with masonry connectively, instead of each one or two having their own bed.

The chimney is 120 feet high, and is reported to be of an average width of 10 feet ; in shape it is square (instead of round or octangular), which is for well known reasons objectionable ; it is also not provided with any anchorage, and is therefore cracked in several places.

Before the works can be started again this chimney would have to be repaired and provided out side with proper iron anchorage.

Hot blast ovens.—For the heating of the blast, there are provided two Whitwell apparatus, one for each blast furnace. The addition of a third apparatus as a reserve would be very desirable, as without it, when one of the apparatus would require repairs or to be cleaned, which frequently occurs, the blast furnace connected with it would have to be worked with cold blast, which requires more fuel and occasions irregularity in the work.

Blast furnace gases.—With reference to the blast furnaces of the establishment, it is inconceivable why the utilization of the valuable gases evolved as fuel has been entirely neglected, and were allowed to

escape. The gases from a blast furnace consist chiefly of about 30 per cent carbonic oxygen gas (Co), 3 to 4 per cent heavy carburetted hydrogen gas $(C_2\ H_4)$, and about 60 per cent nitrogen, the rest being carbonic acid, water, steam, &c. This gas mixture, when purified, is powerful enough and in sufficient quantities to heat all the boilers and the hot blast ovens belonging to the blast furnaces from which the gases have been taken. In the present instance 30 *tons of coal* would have been *daily* saved. The necessary arrangement for catching, purifying, and distributing the blast furnace gases could be easily and cheaply applied, and is urgently recommended to be introduced, before the works are started again.

Blast furnace slag.—Neither is there any arrangement for the utilization of another subsidiary product, namely, the blast furnace slag. Blast furnace slags can be converted into cement, artificial stones, and into so-called "slag wool." It consists of about 38 per cent silicic acid $(Si\ O_2)$, 22 per cent aluminia $(Al_2\ O_3)$, 31 per cent lime $(Ca\ \ O)$, the rest being magnesia, gypsum, and other unimportant constituents.

To make the *cement*, the hot liquid slag is run into water, when it is granulated; the granulated mass is then ground into powder, and this again mixed with one to two per cent of pure limestone or chalk and burnt; the result is a cement of a superior quality.

For the production of *artificial stones*, the granulated blast furnace slag is mixed with a little lime cream; it is then pressed in the desired moulds and dried.

"*Slag wool*" is produced by leading water steam, of a pressure of about two atmospheres, under a right angle, into a thin ray of slag: the produced slag wool looks like cleaned cotton and is used for the packing of steam pipes, the wadding of ice cellars, and in general as an insultator against heat.

Ore crusher.—There is no machine provided in the iron works for crushing the iron ores and the limestone; this used to be done by coolies An ore crusher, a simple and inexpensive machine, would have done this work cheaper and certainly more effectively.

Pig iron.—The product of the blast furnace was 40 tons of grey pig iron for castings per 24 hours for both blast furnaces. The pig iron was run into sand and allowed to get cold; it was partly sold in this shape and partly remelted in the foundry.

The following is an analysis of it:—

Iron, metallic	... ...	90·58 per cent.
Carbon combined	... ...	0·14 „
„ graphite	... ...	2·70 „
Manganese	... ...	0·97 „
Silicon	... ...	4·13 „
Phosphorus	... ...	1·36 „
Sulphur	... ...	0·12 „

Foundry.—The buildings holding the foundry are too far situated from the blast furnaces to allow of the pig iron to be transferred to the buildings direct in a liquid state, for being cast in the moulds without being remelted in the cupolo furnace.

It is an old erroneous notion that the pig iron taken *direct* from the blast furnace furnishes castings of an inferior quality than when remelted in a cupolo furnace. The only disadvantage which can be alleged against the direct casting, namely, want of uniformity in the casting, can be cancelled by suitable arrangements and manipulations during the process of casting. To explain and to prove this would lead us too far. Suffice it to mention that the process of direct casting from the blast furnace without the intervention of the cupolo furnace has lately been practised with success in several English and German iron works, and for a long time in Austria and Sweden.

The remelting of the pig iron should be resorted to only for the purpose of utilizing the Sunday production of the blast furnaces and the scraps of the foundry, or for the production of special qualities of cast iron for certain purposes, such as pottery castings or ornamental objects. In general, the remelting of the pig iron serves only for the convenience of the management of the works, or to remedy irregularities; for when the blast furnace is irregularly worked, unequal qualities of pig iron are produced, which of course render the direct casting process impossible. Through careless or incorrect management in working the blast furnace, sometimes too much carbonised and sometimes too little carbonised pig iron is turned out, both unsuitable for castings; but through alloying both together they can be profitably used for castings by means of the cupolo furnace.

Cupolo furnaces.—For remelting of the pig iron the Bengal Iron Works have four cupolo furnaces of the approved system, "Ireland." The blast is effected by a ventilator and a Roots blower, the latter

decidedly preferable to the former. The defect about the cupolo furnaces is the absence of a lift for pig iron and coke. These materials were carried to the furnace top by coolies upon a staircase. Two simple water cask elevators (one for each couple of furnaces) would remedy this shortcoming at a small expense.

Foundry shops.—The foundry workshops are in two separate buildings—one for light, the other for heavy castings; the latter is therefore provided with five cranes. Connected with the foundry is a workshop for finishing the castings. This workshop contains laths of varying dimensions, two drilling machines, one planing machine, one pipe-testing machine with all appurtenances, and also a movable crane for serving all this machinery. To work the whole of the workshop machinery there is a horizontal steam-engine with boilers, which also works the Roots blower of the foundry. For working the ventilator of the other foundry there is a portable steam-engine.

The clay and sand required for the foundry are prepared in a separate building. This preparation is done by two mortar mills driven by a portable steam-engine.

Drying furnaces.—For drying off the casting cores and clay moulds, there are well built drying furnaces. All that may be objected to in these is, that they are not arranged for being fired with inferior cheap fuel.

Fuel of an inferior quality offers a double advantage in this instance—the first, that a cheaper kind of fuel may be used; the second, that it gives a more uniform heat, which is essential for drying furnaces. When drying furnaces are heated with good coal, there is a danger of the objects to be dried lying nearest the fuel to become over-heated ("burnt") before the more distant objects have been sufficiently dried; indeed, experience has shown that *that* fuel is most suitable for drying furnaces which can just barely maintain itself in a burning state, even with a good draught. Many iron works in Germany and in France have therefore found it profitable to prepare the coke from the coals themselves, as the subsidiary products of coke-making, namely, the escaping gases and the residue in the washing apparatus, can be utilized, the former for heating steam-boilers, and the latter for heating the drying furnaces.

Socket pipes.—The way and manner in which socket pipes were prepared in the foundry was obsolete and defective; these used to be cast horizontally—a process which rendered the labour difficult and the outturn small and faulty. Socket pipes must be cast *vertically*, if their production is to be profitable. To explain the two systems and the reasons of the superiority of one over the other would be too long and out of place here. I will only add that the arrangement for casting vertically can be easily added to the present one.

Arrangement for tiering pipes.—The arrangement for tiering the pipes is equally unpractical and unsuitable for large operations. This arrangement also may be altered without great expense.

Out-houses.—All those out-houses, such as offices, scale-houses, store and dwelling houses and others, which were solidly built, are now in good preservation; but those which were built of inferior material are already dilapidated, and impart to this part of the group of buildings a somewhat ruinous appearance.

SUGGESTIONS.

From what has been reported it may be seen that the Bengal Iron Works are worth reopening; and if their management be entrusted to experienced and conscientious professional men, they should turn out a prosperous investment. The situation is well chosen; the raw materials are near and cheap; and the railway is also near for the conveyance of manufactured goods.

The superiority and good condition of all the machinery and the solidity of the chief buildings prove that the undertakers were imbued with the best intentions to render the establishment good, solid and durable; only it appears that the technical management was entrusted to men of deficient professional experience.

The greatest part of the shortcomings, however, mentioned in the report, may be remedied without great costs. Strictly speaking, the existing arrangements have to be *completed* rather than altered, and this should be done before the works are started again.

The chief condition of success in an iron work is its *continuous* and *full* function. The production must be driven to a maximum, so that the expenditure on management, interest of capital, &c., which are exceptionally high in India, should be as much as possible distributed over a high production.

F MORAR;
26*th October* 1881.

RITTER C. VON SCHWARZ.

REPORT ON THE FINANCIAL PROSPECTS OF IRON WORKING IN THE CHANDA DISTRICT.

RAW MATERIALS.

Iron ores.

The most important and, at the same time, best situated deposits of iron ores in the Chanda District are the *specular iron cres* at Lohara, longitude 79° 47½' E., latitude 19° 22' N., and the *magnetites* at Peepulgaon, longitude 79° 34' E., latitude 20° 23' N.

The following is the chemical composition of these iron ores:—

	Lohara ores.	Peepulgaon ores.
Metallic iron	69·00 per cent.	69·00 per cent.
Oxygen in combination	29·57 "	26·29 "
Mangansesquioxide	0·10 "	...
Silica	0·84 "	4·21 per cent.
Alumina	0·43 "	...
Lime	0·05 "	0·50 per cent.
Sulphur	0·01 "	...

Each of these deposits forms a continuous accumulation of compact iron ore, constituting a hillock and is prolonged deep under the general level of the country. The ores are found in such quantities in these places that an Iron Work producing 80 tons of rails daily might be fed from each deposit for about 100 years without resorting to the deeper-lying ores at greater expense. Besides these two deposits there are other places in the Chanda District where iron ore is found, namely, Lankachen, Ratnapur, Dewalgaon, Ogulpet, Metapur, Gunjwahi, Joonona, Kandeshwa and others; the ores in those places, however, being either of a poorer quality and containing more impurities, or not being so advantageousl situated as those of Lohara and Peepulgaon, deserve, at least for the present, no consideration.

The iron ores of Lohara have in their few impurities all the component parts necessary for the formation of such blast furnace slag which has the proper chemical composition in regard to the ash contents of the fuel, so that 3 per cent only of flux will be required for smelting these ores in the blast furnace by means of charcoal.

As specular iron ores are easier treated in the blast furnace than magnetites (as is well kuown to every professional iron-worker), I hold it to be correct on this ground, and on others (explained on page 5), to take up for working, first of all, the iron ores of Lohara (see Appendix No. 1, page 27).

Vegetable fuel.

For the reduction of these iron ores in the blast furnaces the forests of the Chanda District offer sufficient vegetable fuel, and at prices sufficiently cheap for the production of iron and steel of the best quality, in large quantities, and at competition prices.

The forests of the Chanda District cover an area of 3,325 square miles, of which, however, at present owing to considerations of carriage, only that part should be exploited as fuel for the reduction of the ores which lies within a circumference of about 20 miles radius round the place which has been chosen as the most suitable for the erection of an Iron Work.

This part of the forest covers about 520 square miles, capable of yielding 16,000 tons of dry wood per square mile in its present condition.

According to information from the Conservator of Forests, Central Provinces, from this quantity must be deducted about 30 per cent for reserved trees, which, owing to the valuable quality of their wood, or owing to other reasons, may not be made into charcoal, so that about 11,000 tons of wood per square mile may safely be counted upon as available for reducing to charcoal.

The weight of the various woods of the Chanda Forests is, on an average, 50 lbs. per cubic foot (see Appendix No. 9, page 29); therefore 30 per cent greater than of the woods (chiefly fir and pine) used in Sweden and Styria for charcoal; the Chanda charcoal being thus specifically heavier is, weight for weight, far more valuable for the smelting of iron ores (see Appendix No. 2, page 27).

According to an estimation of the Conservator of Forests, Central Provinces, the area of 520 square miles of forest, lying round the site of the projected Iron Works, may yield 32,000 tons of charcoal yearly and be regenerated in forty years.

The same authority maintains that the production of charcoal on a large scale, and carried on systematically, improves forests; this, although apparently paradoxical, has been proved by experience in those parts of Sweden and Styria where vegetable fuel is used on a large scale in the production of iron. The reason for this is not far to seek. The products of the forest being in greater demand and more valuable, the science of forestry has been called in to show the way to a more correct system of conserving and increasing the contents of forests. The improved and cheaper means of transport, rendered necessary for an Iron Work near a forest, render also cheaper the carriage of building timber and other forest produce, whereby they become cheaper; saw-mills and other wood-working machines may be advantageously connected with an Iron Work establishment, as this can furnish cheaply the necessary steam-power and supervision.

Coal.

Whilst there is sufficient charcoal in the Chanda Forests for the production of *pig iron*, the coal of the Warda-Godavery Valley is good enough for the refining process, namely, the conversion of the pig iron into *finished iron* or *steel* if the necessary arrangements are made, suitable for this quality of fuel. Judging from borings and outcrops, the sources may be estimated to contain 2,525 millions of tons, of which 1,714 millions are available. The most important seams are those of *Wun*, *Pisgaon*, *Ghugus*, *Bunder* and *Warora.*

Of all these coal-fields, however, the Warora seam only is now worked and produces monthly about 7,000 tons of coal, of which 5,000 tons are bought by the Great Indian Peninsula Railway.

Owing to the small demand of coal the working of this mine is limited; if more use were made of it, the working expenses would be proportionally reduced. It is to be regretted that the quality of this coal is not so satisfactory as the quantity.

An analysis of the Warora coal shows—

	Large coal.	Slack coal.
Fixed carbon	45·6 per cent.	35·5 per cent.
Volatile matters (combustible)	26·0 „	26·4 „
„ „ (not combustible) ..	14·0 „	13·0 „
Ashes	14·4 „	24·0 „

The reasons why this coal must be described as of inferior quality, as regards its fitness for pyrotechnic uses, are—

(1) its insufficient contents of fixed carbon;

(2) its insufficient contents of hydrogen, not combined with oxygen;

(3) its large contents of ashes.

All attempts to reduce this coal to coke, suitable for the blast furnace process, have failed, owing chiefly to its deficient proportion of fixed carbon and (not with oxygen combined) hydrogen. It is well known (although not theoretically proved) that it is generally the hydrogen which imparts to the coal the caking quality necessary for its reduction to coke, but numerous trials have shown that the Warora coal when heated does not cake, but crumbles to pieces, which pieces give indeed coke, but of a quality suitable only for forge fires, or for lime-burning, and not for blast furnaces (see Appendix No. 3, page 27).

The coal of Warora is good enough, however, for producing all the pyrometric effects necessary for puddling and heating furnaces, and to provide the glow furnaces for Bessemer ingots and sheet iron with the necessary heat. This coal is also good enough for the cementation process (production of blister steel) and the temper process (the production of malleable iron); but it is not suitable for the open-earth process and for the production of crucible steel in the (reverbatory) flaming furnace, as these processes require a very high temperature. Of the other coal fields of the Warda-Godavery basin, the coal of *Pisgaon* (Berar) appears to me the most hopeful, owing to its larger contents of fixed carbon. Its analysis is as follows:—

	Large coal.	Slack coal.
Fixed carbon	65·1 per cent.	36·3 per cent.
Volatile matters	19·2 „	32·2 „
Ashes	15·7 „	31·5 „

The large coal of Pisgaon contains, therefore, 20 per cent more fixed carbon than the large coal of Warora; notwithstanding the superiority of this coal, no arrangements have yet been made to work the seam.

Limestone.

For the reason explained on page 1, the reduction of the iron ores of Lohara in the blast furnace will require 3 per cent only of limestone as a flux. Excellent limestone for this purpose is to be had in the neighbourhood of Warora; its analysis is as follows :—

Carbonate of lime and magnesium	95·0 per cent.
Silica	2·5 „
Alumina and oxide of iron	2·5 „

Fireproof material.

More important than the supply of limestone is the supply of suitable and cheap fireproof material. English fireproof bricks would cost, delivered in Chanda, Rs. 16 per 100. Now, the requirements of an Iron Work, producing about 80 tons finished iron or steel per day, would be 300,000 tons per year, giving thus an expenditure of Rs. 48,000 yearly for firebricks alone; but—

(a) fire-clay of a good quality is found along with the coal in the Warora Colliery; the following is an analysis of this fire-clay :—

Moisture	4·10 per cent.
Organic matter	4·30 „
Silica (sand)	2·40 „
Silica (in silicates)	63·20 „
Alumina (Al_2O_3)	18·80 „
Oxide of iron	0·50 „
Iron in pyrite	1·87 „
Carbonate of lime	1·80 „
Alkalis and sulphur	2·03 „
Loss	1·00 „

This clay is not so good as first-class English fire-clay, but is good enough for most parts of the iron-melting furnaces.

(b) Near Chanda is also found steatite (Mg. O Si O_2), which, mixed with one-fifth part fire-clay, is well known to give very refractory firebricks.

Fire-proof bricks could be made at the Iron Works for Rs. 2-8 per 100, and about four-fifths of the whole requirement could be covered by these bricks; only for certain parts of the blast furnace and the gas furnaces, it would be necessary to import English firebricks, namely, one-fifth of the whole amount.

AMOUNT OF PRODUCTION.

The amount of iron or steel which can be produced yearly with these raw materials will depend on the quantity of charcoal which the forests near the Iron Work can furnish without irretrievable injury to them; this has been estimated at 32,000 tons per year (*vide* page 2), and with this charcoal may be turned out 25,000 tons of finished iron per year. In case it may be found desirable in the future to considerably enlarge the Iron Work, recourse may be had to the more distant forests situated south and south-east of Chanda (See plan No. 1) for charcoal for the production of *pig iron*. In this case it will be advisable to erect other blast furnaces near these forests, with the view of reducing the iron ores of the contiguous deposits and of conveying the pig iron thus obtained to the other Iron Works, situated nearer the sources of *mineral* fuel, for the purpose of converting it into finished iron. By these means the whole 3,325 square miles of forests in the Chanda District might make it possible for 260,000 tons of iron or steel being produced yearly.

BEST SITUATION FOR AN IRON WORK.

For the production of one ton of finished iron or steel the following quantities of the available materials are necessary :—

	Tons.
Iron ores	1·80
Charcoal	1·30
Mineral coal from Warora	3·00
Limestone	0·03

From these proportions it may be seen that the quantity of fuel is more than double that of ore. On this account, and as besides, for well-known reasons, the carriage of ores, even weight for weight, is cheaper than the carriage of fuel, and store of them easier kept, an Iron Work should always be built as near as possible to the sources of the fuel.

It may also be remarked that the carriage of charcoal is dearer than the carriage of mineral coal.

A suitable place for the Iron Work would be Durgapur on the Fraee stream. This place is surrounded by forests, has enough water even in the driest season, has a firm ground for building and heavy machinery, cheap stone and lime; has also the advantage of being situated somewhat high, and is therefore more within the influences of the breezes, which would keep the Iron Work cool.

This place could also be cheaply put into communication with Lohara and Warora by means of a Tramway, as there are neither hills to cross nor expensive bridges to make. The suitability of this place, however, is best proved, I think, by the annexed plan, No. 1, and attention should also be drawn to the important fact that this place, on the Fraee stream, is the only one between Lohara and Warora on which a sufficient supply of water all the year round may be relied upon.

In further support of the preference of this place an account of its water-supply, it may be mentioned that the want of this convenience has caused to the Bengal Iron Works Company an extra expenditure of nearly Rs. 50,000 (see Report on the Bengal Iron Works, page 1).

RAILWAYS.

Under the present circumstances, the best means of connecting the iron mine of Lohara and the Warora Colliery with the Iron Work would be a portable Tramway. This would cost, everything included, about Rs. 12,000 per mile. The whole length of the Tramway would be 55 miles (see plan No. 1); the total expenditure would therefore be Rs. 6,60,000.

The building of an ordinary Railway would, for the present, not answer; it would cost about nine times as much as the tramway (the Warda-Warora Coal State Railway was built at an expenditure of Rs. 1,06,000 per mile), and would hardly pay any interest on the capital expended, especially as the extension of such a Railway eastwards can hardly be expected to be undertaken for a long time.

Nevertheless, should an ordinary ("pucca") Railway become necessary in the future in consequence of an enlargement of the Iron Work, or through other reasons, the Tramway being portable, could be transferred elsewhere and advantageously utilized as a way for transport of charcoal and other forest produce.

Besides, the proposed Tramway, traversing the best and thickest parts of the Chanda Forest, could at once be utilized for transport of forest produce; combining also the best cultivated and best populated stretch of the Chanda District, it would advantageously connect this with the main Railway at Warora.

This tramway line has been proposed after consulting and with the approval of the Conservator of Forests for the Central Provinces and the Deputy Commissioner of the Chanda District. This, and the reasons developed on page 1, are further grounds for first taking in hand the iron ore deposits of Lohara. A modification of the tramway project could take place only if the often spoken of railway extension between Chanda and Warora were definitely resolved upon.

CAST-IRON GOODS.

There is no doubt that, with such excellent raw material as the Chanda District possesses, an excellent quality of cast-iron may be produced; and it follows also that only such cast-iron goods should here be turned out in which a good quality of iron is of importance, and which are, therefore, sold at higher prices.

Heavy castings.

For the production of such heavy castings as plumber blocks, steam engine flywheels, and other heavy parts of machinery, also of weights, railings, columns, lamp-posts, &c., the raw meterial of the Chanda District is too valuable.

Pottery castings.

It is further unsuitable for the fabrication of cast pottery and objects of art, as all such things have to be run fine, delicate forms have to be filled, and smooth surfaces given to the castings; for all such goods phosphorus in the cast-iron is necessary, which is not found in the ores of the Chanda District.

Cast-iron railway wheels.

An article very much in use, and the manufacture of which would be particulary suitable to our circumstances, would be *cast-iron railway wheels*.

It is a strange fact that for a long time, and almost exclusively, cast-iron wheels have been used on the railways on the American Continent, not only with goods and passenger wagons, but also with locomotives, whilst in Europe they are generally used with goods wagons, never with passenger wagons, and by no means with locomotives.

Considering the enormous extension of railways in America,—the mileage being greater than that of England, Germany, Austria, France, and Russia taken together—it might be correctly presumed that the Americans have good experience in this matter.

When the great difference in the price of a cast-iron wheel and a wheel of wrought-iron and steel is considered in conjunction with the enormous quantity used, the subject becomes of some importance.

On the other hand it may be assumed that the Engineers in Europe, to whom the use of cast-iron wheels is no secret, have also good reasons for abiding by wrought-iron and steel wheels. The fact of cast-iron wheels being, on European railways, limited to goods wagons, would point to a want of confidence in the safety of such wheels against brittleness, whilst the confidence in America in the freedom from brittleness can only be due to the wheels being made of a more reliable quality of cast-iron and under a corresponding manipulation.

To enter into the details of manufacturing this article would be out of place here; let it suffice to say that in this matter the greatest care has to be used in the choice of the materials, as well as in the fabrication, if the article is to be free from flaws and reliable in every respect.

Before putting in use, each wheel should be subjected to the most rigid tests for solidity, strength, sufficient hardness in the flanges, and general manufacture.

The material used in America for cast-iron wagon wheels is grey pig-iron, obtained from rich and pure red iron ore melted with charcoal, *corresponding, therefore, exactly with our circumstances.*

The usual duration of such wheels is of that degree that they are allowed to run 60,000 miles in full confidence before they are subjected to new tests as to their further utility.

At the Philadelphia Exhibition four such wheels were shown which had run 450,000 miles without having suffered in substance or appearance.

Malleable castings.

Another speciality, suitable for the present circumstances, is the production of *malleable castings.* For this article also pig-iron of the best quality (reduced with charcoal) is adapted. To explain it in a few words, the cast articles are embedded in material giving off oxygen, and are slowly heated, whereby the carbon is driven out of the cast-iron to a certain degree, the final product being one of steel-like nature. As a decarbonising means in our case the manganese ores of Malaghar and Ramtek (see Plan No. 1) can be made use of. The fabrication of malleable iron has lately been brought to great perfection in certain parts of Europe and America. The following articles might be here produced; ploughshares, scythes, hay-forks, rakes and other agricultural implements; also stirrups, horse-bits, keys, small wheels, certain parts for guns, rifles and other weapons, double eyes and other parts of machinery, and in general such articles of complicated shapes in which great strength is not required; articles which it would be difficult to make of forage-iron. It is scarcely necessary to mention here that most cast-iron articles may be turned out *direct* from the blast furnace, without re-melting in the cupola furnace.

SUBSIDIARY PRODUCTS.

The subsidiary products of the blast furnace, as the gases and slag, can and should be utilized,—the former for the heating of the boilers and hot-blast ovens; the latter for the fabrication of cement, artificial stones, and slag wood (*vide* Report on the Bengal Iron Works, page 2).

THE BESSEMER PROCESS.

From the purity and uniformity of the ores and fuel treated of, it may at once be concluded that the product of the blast furnace will also be pure and uniform, and that it will, therefore, be possible to allow the pig-iron to run in a fluid state *direct* from the blast furnace into the Bessemer converter, whereby the cost of re-melting would be saved, as is successfully done in Carinthia, Styria, and Sweden, where the working is carried on under conditions similar to those in our case.

The finishing process of rolling the Bessemer ingots into rails, tyres, plates, &c., requires no particularly high temperature, and can, therefore, be effected with Warora coal of second quality, *viz*, *slack coal* at Rs. 2 per ton.

SPIEGELEISEN.

The "Spiegeleisen" necessary for the production of steel in the Bessemer converter cannot be obtained from the iron ores of Chanda, as, notwithstanding their purity, their contents of manganese is very slight; "Spiegeleisen" would, therefore, have to be imported.

"Spiegeleisen" contains from 5 to 15 per cent manganese; it would lead us too far to explain why this ratio of manganese is necessary for the production of "Spiegeleisen"; suffice it to say that hitherto the existence of "Spiegeleisen" free of manganese has not been proved (see Appendix No. 4, page 28). For the production of (ingot iron) "Flusseisen" (a product containing only 0·05 to 0·10 per cent of carbon) in the Bessemer converter, it is not required to add "Spiegeleisen." *Girder plates, boiler plates, rod, angle, and square iron, and rolled beams* of the *stronger* kind *wagon axles*, and *iron rails*, could be turned out cheaply in the Bessemer process, as these descriptions of goods can be made of (ingot iron) "Flusseisen," and the cost of "Spiegeleisen" is avoided.

The scraps remaining when making rails are generally used up in the open-hearth process, in the cupola furnace, or in the Bessemer converter, where they are melted down with the pig-iron. It has already been shown (page 3) that under the present circumstances the open-hearth process cannot be used; the other usual resources for utilizing the scraps of rails is rationally resorted to only where no better alternative remains. These scraps, however, yield particularly suitable material for the manufacture of wire and thin hoop-iron, a process which has been in vogue for some years with success in Cleveland, and has lately been initiated in other Bessemer Works. A Bessemer establishment, producing daily 72 tons of rails, can in this wise turn out daily 8 tons of wire or of hoop-iron.

THE PUDDLING AND WELDING PROCESS.

It has already been mentioned (page 3) that the Warora coal can be advantageously used in the puddling and heating (welding) process; but it should be mentioned also, with regard to the purity and richness of the iron ores, that a modification of this process has come into use in America, consisting in the adding of iron ores for furthering decarbonisation, whereby the time of finishing the puddling process is shortened, the loss of iron, which used to be about 10 per cent is reduced to 2 per cent, and there is a corresponding saving in coal and labor. The puddling process has lately been much diminished in Europe, owing to the undoubted success of the Thomas Gilchrist dephosphorising methed applied to the Bessemer process, as, by this method, the cheaper pig-iron containing phosphorus can be worked, which was before possible only in the puddling furnace; but the latter will still maintain itself—

1*st*, where there is an object to manufacture *fine* kinds of iron, or rolled iron goods of *complicated* form, as wire, fine hoop-iron, thin sheet-iron, thin angle and U-iron, &c., because the reduction of the 14 inch thick Bessemer blocks of compact material to small dimensions or complicated forms is combined with much and costly manipulation;

2*nd*, for turning out certain qualities of iron and steel, which cannot be produced in the Bessemer converter, for instance, blister and Brescian steel.

THE DIRECT PROCESS.

It will not be out of place here to bring to notice a new process of iron and steal-making directly of ores, namely, the "*Landore Process*," which, if not at present, may, under the condition of the projected Iron Work, deserve consideration in *future*.

This process consists in melting a certain amount of grey pig-iron of the best quality in an open-hearth furnace, and adding to the thin fluid metal bath so obtained iron ores till the matter has been decarbonised. It is the oxygen in the iron ore which is here the decarbonising factor, the metallic iron being reduced and dissolved in the metal bath.

This adding of iron ore is continued till the whole of the pig-iron has been decarbonised (which is experimentally ascertained), when "Spiegeleisen" or "Ferromanganese" is added, as in the Bessemer converter, for the production of a given quality of steel.

It is scarcely necessary to prove that for this process iron ores of the best quality are required; in Landore these are imported from Mokta in Algeria; they contain 62 per cent metallic iron and have no injurious impurities. Now, these ores cost, delivered in Landore, about Rs. 13 per ton, whilst the iron ores of Lohara contain 69 per cent of metallic iron (7 per cent more), and would cost, delivered at the Iron Work in Chanda, Rs. 3½ per ton.

It should be, however, pointed out that the process under explanation requires a very high degree of heat, as the metal bath has to remain perfectly liquid even in a decarbonised state; the metal bath must also be covered with a layer of slags, 3 inches thick, as a protection against the flame hovering over it, which would act injuriously upon the ores floating on the surface of the bath, till they are dissolved.

This cover of slags acting as a bad conductor of heat, a temperature of 1900° centigrade is required to work the Landore process successfully. It may be doubted whether so high a temperature can be obtained with Warora coal (being poor in carbon), even with the assistance of Siemen's regenerators, but it might be obtained with the Pisgaon coal which has 20 per cent more carbon than the Warora coal.

Should, therefore, in due time the Pisgaon seam be opened out, this process would have a chance of giving excellent results with the Lohara ores. This process has been in use in the Landore Works already 12 years with ever-increasing results: by this time there are 24 furnaces at work, producing together about 2,000 tons of steel per week. The steel turned out with this process is well-known for its uniformity and durability, and is therefore preferred in the English arsenals to all other brands. It is due chiefly to the difficulty of finding so pure and rich ores, and to their high cost, that this process has not been more generally adopted (see Appendix 5, page 28).

ARTICLES FOR EXPORT.

The natural resources of the Chanda District offer not only the prospects of supplying India with a considerable portion of her iron and steel requirements, but also of producing articles for exportation to England—articles which are not made in England, but are imported in considerable quantities from the Continent of Europe.

Ferromanganese.

Such are *Ferromanganese*, a mixture of metallic iron with 30 to 75 per cent of metallic manganese and a few per cents of carbon; it is used as an addition in the Bessemer and open-hearth processes, and also in the cast-steel crucible for the production of certain kinds of steel of special hardness for bandages, cutting tools, manganese-steel, &c.

The price of this article is very high, and fluctuates according to the quantity of manganese it contains,—from £15 to £25 per ton delivered at Sheffield. The best part of this article England imports from Horde in Germany, and Terrenoire in France. The raw materials required for the production of ferromanganese are pure charcoal pig-iron (granulated), and manganese ore containing iron.

There are three systems for the manufacture of ferromanganese, namely, in the crucible, the open-hearth, and the shaft furnace. To explain all these methods would lead too far; suffice it to say that for our conditions the production of ferromanganese with the shaft furnace (Système "Terrenoire") would be most suitable.

There is in Ramtek (see plan No. 1) manganese ore of the following chemical composition:—

	Per cent.
Metallic manganese	54·60
" iron	6·50
Oxygen in combination	26·50
Silica	6·00
Lime	1·20
Combined water a. div. impurities	5·20

This manganese ore, with the pig-iron obtained from the Lohara ores by means of charcoal, would yield a material for the production of Ferromanganese of an excellent quality.

Another manganese ore is found in Malaghar (see plan No. 1), Wún District, containing 26 per cent metallic manganese; it is of an inferior quality, and, although nearer, it cannot compete with that of Ramtek.

Brescian Steel.

A second export article to England would be the so-called "*Brescian* or *Milan Steel.*" This is a kind of puddling steel, made of a pig-iron free from phosphorous and sulphur, and is an article of commerce in great demand and much esteemed.

In former times, Brescian or Milan steel was only made, as its name indicates, in the districts of Milan and Brescia, and was made with charcoal in the old charcoal hearth. The demand for this article, however, in England and on the Continent of Europe was greater than those districts could satisfy, and Corinthia and Styria are now supplying the greatest part of it.

As material for this product serves pure, white and grey charcoal pig-iron, which are converted in the puddling furnace by means of brown coal or turf into raw steel. It is then rolled by means of the welding process into square bars from ½ to ¾ inch thick. The bars are quickly cooled in water, broken, sorted according to the appearance of the breach, and packed in cases for export to England, France and Germany.

The price of Brescian steel delivered in Sheffield is £18 per ton.

THE LABOR QUESTION.

The disproportionally heavy cost and disadvantages arising from climate and social circumstances connected with the maintenance of a European staff of workmen point to the advisability of having recourse, as much as possible, to *native labor;* on the other hand, there is in the native a deficiency of practical professional training and a lower degree of physical and moral strength. Professional training can, however, be imparted to the native, and I believe he can be made to learn the work required at a blast furnace and rolling mill, if he be treated at it with gentleness and patience, if he be strictly controlled, if he be not worked too hard, and if his religious and other prejudices be respected; his physical strength will rise with better diet obtained by means of better wages.

The usual 12 hours of daily attendance ruling in Europe would have to be reduced to 8 hours. It would also be advisable to promise rewards to the European workmen for every native trained sufficiently to replace a European.

There are some branches of iron-work which natives will learn very quickly, such as the manufacture of wire, hoop-iron, malleable iron, ferromanganese, blister steel, and other operations requiring less physical strength, but more quickness of movement or manual cleverness.

WATER-POWER.

No suitable place can be found in the Chanda District where there is natural water-power available for the driving of the machinery of an iron work.

The only stream in this district which might be made to furnish water-power is the Winganga, called Prenhita after its union with the Wurda stream, north of Bemballa (see Plan No. V). This stream has numerous cataracts, which, if concentrated by a canal six miles long, would give a fall of 40 feet.

The quantity of water amounts during the dry season to about 100 cubic feet per second, which with the 40-feet fall, would give *theoretically* an effect of about 520 horse-power.

Through the application of a Jonval turbine (the most suitable motor for our conditions), this water-power might be made to furnish a *real* effect of 350 *horse-power;* the use of this water-power for the iron work is, however, not suitable, and this for the following reasons :—

(1) In the rainy season this stream rises often 50 feet, when the machinery worked by it would have to be stopped, a contingency which an iron work could not endure, as the laying cold and reheating of the furnaces are connected with very great expense of money and time, and with other inconveniences which it would be too long to explain here.

(2) The locality of the available water-power is too much out of the way, so that the saving of fuel would be more than counterbalanced by the greater cost of carriage of the raw materials and the manufactured goods.

(3) Water-power is in general of less value for an iron work because the necessary steam-power for the driving of the machinery may be produced, in most cases, with the gases drawn from the furnaces, that is to say, no extra fuel is required for heating the boilers. The gases of a blast furnace (of a production of 30 tons of pig-iron per day) supply about 150 horse-power; the gases of a furnace for Bessemer ingots furnish 130 horse power, a puddling furnace gives 20 horse-power; and a heating furnace for bar-iron 25 horse-power.

The water-power of the Winganga may become of good use for other industries in the future, when the communications of the district will have been developed.

A short stoppage of a paper, cotton, rice, or saw mill is no great loss, as the time of the inundation can be usefully employed for repairing the machinery, taking stock, &c., which operations, by making a virtue of necessity, could be always reserved for the season of the freshes.

For such establishments water-power has also more value, as it can be assumed that each of its horse-power is equal to one cwt. of coal per 12 hours.

COST OF RAW MATERIALS.

Iron ore.

The cost of quarrying the iron ore at Lohara and carrying it to the tramway may be estimated at annas 14 per ton, the carriage by tramway from Lohara to the iron work, 38 miles, at anna 1 per ton per mile ; we have therefore—

	Rs.	A.	P.
Cost of the ore at the quarry, per ton ...	0	14	0
Carriage from Lohara to the iron work, 38 miles, at 1 anna per ton	2	6	0
Total cost of one ton of ore delivered at works	3	4	0

(See Appendix No. 6, page 28.)

Charcoal.

According to information received from the Conservator of Forests of the Central Provinces, *charcoal* may be had at the place of production for Rs. 3—13—10 per ton ; but it may be presumed that with a larger demand the rates of labor and contingencies will rise and increase the present price of charcoal by 30 per cent; it will therefore be safer to estimate the cost per ton at Rs. 5—0—6 (see Appendix No. 8, page 28). The transport of charcoal will also best be effected by a portable tramway.

Owing to the larger bulk of this article, and the somewhat greater precautions required to be taken in its carriage, it will cost about 50 per cent more than that of the ore, namely, annas $1\frac{1}{2}$ per ton per mile.

It should be observed that, according to the information furnished by the Conservator of Forests, Central Provinces, the 32,000 tons of charcoal (which will be required annually) will cause a deboisement of 11 square miles of forest yearly ; with regard to the situation of the forest to the iron works it will therefore be necessary to shift the charcoal tramway once every $3\frac{1}{2}$ years. Assuming the charcoal tramway to be 20 miles, the cost of its shifting every $3\frac{1}{2}$ years will be $20 \times 3{,}000 =$ Rs. 60,000 (Rs. 3,000 per mile), which must be distributed over the cost of carriage of the charcoal. Now, tons $32{,}000 \times 3\frac{1}{2}$ (years) $= 112{,}000$ tons ; therefore the cost of shifting of tramway per ton of charcoal will be $\frac{\text{Rs. } 60{,}000}{\text{tons } 112{,}000} =$ annas 9.

The average distance over which the charcoal will have to be carried is 15 miles. The cost of carriage of the charcoal will therefore stand per ton—

	Rs.	A.	P.
Net carriage	1	6	6
Proportion of shifting of Tramway every $3\frac{1}{2}$ years	0	9	0
Total ...	1	15	6

The total cost of one ton of charcoal delivered at the Iron Works will therefore be—

	Rs.	A.	P.
At the place of production	5	0	6
Total cost of carriage (annas $2\frac{1}{4}$ per ton per mile)	1	15	6
Total ...	7	0	0

It will be observed that in this calculation only the actual expenses have been taken into account, and not the value of the trees to the Forest Department ; but it should be remembered that, in an indirect way (explained on page 2), the Forest Department will be sufficiently compensated by an iron work situated near its forests.

Coal.

The prices of coal in Warora are Rs. 5 per ton large coal and Rs. 2 per ton slack coal ; its carriage to the Iron Work per Tramway would be $\frac{3}{4}$ anna per ton per mile.

The carriage of the coal is taken 30 per cent. lower than that of the ore, as it will chiefly be done by return train ; all other goods will be carried to Warora from the iron works, and the coal to the iron works from Warora. These other goods will be those made in the iron work, but also forest produce

and the agricultural produce of the well-cultivated part of the country situated on the Winganga stream, which agricultural produce is sure to be increased through the tramway connecting this district with the main railway at Warora. The total cost per ton of coal delivered at the iron work will therefore be :—

	Rs.	A.	P.
Large coal, cost at Warora	5	0	0
Carriage from Warora, 17 miles, at 9 *pies per ton*	0	13	0
Total	5	13	0
Slack coal, per ton at Warora	2	0	0
Carriage from Warora to the iron works, 17 miles at 9 *pies* ..	0	13	0
Total	2	13	0

Limestone.

The cost of limestone delivered at the iron works will be the same as that of slack coal, namely, Rs. 2—13—0 per ton.

WAGES.

Skilled labour.

In the beginning at least skilled labor will have to be done by Europeans (See page 10); for certain subordinate operations only suitable natives may be found, as for instance foundrymen, engine-drivers, masons, carpenters and other auxiliary workmen.

The cost of professional work done by Europeans must be assumed as double that in Europe.

Native labour.

A strong native cooly costs at present in the Chanda District *annas* $2\frac{1}{2}$ per day, but wages must be expected to rise to *annas* 4. If the native labourer be assumed to do, in a given time, only half the work a European would do, he would still cost less than half. Unskilled work, such as loading and unloading the work at the cranes, carriage, masonry, carpentry, locksmith's work, and all auxiliary work can be done by natives, and may be estimated at half the cost for which it is done in Europe.

MANAGEMENT, WEAR AND TEAR, &c.

The cost of these is estimated at 35 per cent higher than in Europe. This agrees with the experience gained in other large establishments of the kind in India. There will, however, be an economy in respect of fireproof material, which forms the greatest item in the question of wear and tear, as the raw material is found near the iron work and can be worked up exclusively by coolies.

APPROXIMATE COST OF PRODUCTION.

(1) *Cost of one ton of grey pig-iron—*

		Rs.	Rs.
1·60 tons iron ores	at	3·25	5·20
1·00 „ charcoal			7·00
Wages			3·66
Limestone, 0·05 tons	„	2·80	0·14
Management, wear and tear, &c.			7·00
Total			23·00

(2) *Cost of one ton of white pig iron—*

1·60 tons iron ores	at	3·25	5·20
0·86 „ charcoal	„	7·00	6·02
0·05 „ limestone	„	2·80	0·14
Wages			3·34
Management, wear and tear, &c....			6·30
Total			21·00

(3) *Cost of one ton of rails (Bessemer steel)*—

		Rs.	Rs.
1·19 tons grey pig-iron	at	23·00	27·37
0·06 „ Spiegeleisen	„	130·00	7·80
1·00 „ slack coal from Warora	„	2·80	2·80
0·50 „ large coal	„	5·80	2·90
Wages			10·88
Management, wear and tear, &c.			12·35
Total			64·00

(4) *Cost of one ton of rails (Bessemer iron)*—

1·25 tons grey pig-iron	at	23·00	28·75
1·00 „ slack coal	„	2·80	2·80
0·50 „ large coal	„	5·80	2·90
Wages...			10·45
Management, wear and tear, &c.			12·10
Total			57·00

(5) *Cost of one ton bearing or girder plates of Bessemer iron*—

1·50 tons grey pig-iron	at	23·00	34·50
1·50 „ slack coal...	„	2·80	4·20
0·50 „ large coal	„	5·80	2·90
Wages			12·40
Management, were and tear, &c.... ...			14·00
Total			68·00

(6) *C.st of one ton bar iron, puddled*—

1·50 tons white pig-iron	at	21·00	24·15
0·30 „ iron ores	„	3·25	0·97
1·50 „ slack coal	„	2·80	4·20
1·50 „ large coal	„	5·80	8·70
Wages			11·63
Management, wear and tear, &c.			12·35
Total			62·00

(7) *Cost of one ton rolled wire and thin hoop-i[illegible]lled*—

1·00 tons white pig-iron	at	21·00	21·00
0·30 „ grey pig-iron	„	23·00	6·90
1·80 „ slack coal	„	2·80	5·04
1·50 „ large coal	„	5·80	8·70
Wages			13·36
Management, wear and tear, &c.			14·00
Total			69·00

(8) *Cost of one ton low moor plates, puddled*—

1·00 tons white pig-iron	at	21·00	21·00
0·40 „ grey pig-iron	„	23·00	9·20
1·50 „ slack coal	„	2·80	4·20
3·00 „ large coal	„	5·80	17·40
Wages...			20·20
Management, wear and tear, &c.			22·00
Total			94·00

(9) *Cost of one ton sheet iron, puddled—*

		Rs.	Rs.
1·20 tons white pig-iron	„	21·00	25·20
0·30 „ iron ores	„	3·25	0·97
2·50 „ slack coal	„	2·80	7·00
1·50 „ large coal	„	5·80	8·70
Wages			15·13
Management, wear and tear, &c.			14·00
Total			71·00

(10) *Cost of one ton blister steel—*

0·98 tons bar-iron	at	62·00	60·76
0·20 „ charcoal...	„	7·00	1·40
4·00 „ slack coal	„	2·80	11·20
Wages			10·64
Management, wear and tear, &c.			14·00
Total			98·00

(11) *Cost of one ton Brescian steel—*

0·60 tons grey pig-iron	at	23·00	13·80
0·70 „ white pig-iron	„	21·00	14·70
2·00 „ slack coal	„	2·80	5·60
1·50 „ large coal	„	5·80	8·70
Wages			13·20
Management, wear and tear, &c....			14·00
Total			70·00

(12) *Cost of one ton ferromanganese with 60 per cent manganese—*

0·50 tons grey pig-iron (granulated)	at	23·00	11·50
1·50 „ manganese ore from Ramtek (including transport)	„	7·00	10·50
5·00 „ charcoal	„	7·00	35·00
Wages			16·00
Management, wear and tear, &c.			17·00
Total			90·00

Recapitulation.

Cost of one ton	grey pig iron at the Iron Work	23·00
Do	white do do	21·00
Do	Bessemer steel rails do	64·00
Do	do iron rails do	57·00
Do	bearing or girder plates of Bessemer iron	68·00
Do	puddled bar-iron	62·00
Do	rolled wire and thin hoop-iron	69·00
Do	"low moor" plates	94·00
Do	thin sheet-iron	71·00
Do	blister steal	98·00
Do	Brescian steel	70·00
Do	ferromanganese with 60 per cent manganese	90·00

REMARKS.—In the calculations of the cost of production, the *actual* expenses are only taken into account, *excluding* interest of capital invested in the Iron Work, as well as Government fees and taxes of any description.

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2. The prices are given in rupees, per ton, at the Works.

COMPARATIVE STATEMENT

Showing the Difference of Prices of Iron and Steel Goods in different Railway Stations.

Names of Stations.	Bessemer Steel Rails. English prices.	Our cost prices.	Difference in our favour.	Remarks.	Bessemer Iron Rails. English prices.	Our cost prices.	Difference in our favour.	Remarks.
	Rs.	Rs.	Rs.		Rs.	Rs.	Rs.	
Agra	124·0	111·0	13·0	*Viâ* Ajmere.	109·0	104·0	5·0	
Allahabad	126·0	106·2	19·8	*Viâ* Bhosawul.	111·0	99·2	11·8	
Benares	134·0	114·2	19·8	Ditto.	119·0	107·2	11·8	
Bhosawul	98·8	79·0	19·8	Ditto.	83·8	72·0	11·8	
Bombay	82·0	95·8	...	Ditto.	67·0	88·8	...	
Cawnpore	130·0	110·2	19·8	Ditto.	115·0	103·2	11·8	
Gwalior	133·0	120·0	13·0	*Viâ* Ajmere.	118·0	113·0	5·0	
Jubbulpore	115·0	95·2	19·8	*Viâ* Bhosawul.	100·0	88·2	11·8	
Lahore	143·5	130·5	13·0	*Viâ* Ajmere.	128·5	123·5	5·0	
Lucknow	134·0	114·2	19·8	*Viâ* Bhosawul.	119·0	107·2	11·8	
Mooltan	153·0	140·0	13·0	*Viâ* Ajmere.	138·0	133·0	5·0	
Nagpore	111·5	71·3	40·2	*Viâ* Bhosawul.	96·5	64·3	32·2	
Neemuch	115·5	95·7	19·8	Ditto.	100·5	88·7	11·8	
Warora	112·5	65·3	47·2	Ditto.	97·5	58·3	39·2	

Names of Stations.	Girder Plates and Ship Plates. English prices.	Our cost prices.	Difference in our favour.	Remarks.	Puddled Bar Iron. Swedish prices.	Our cost prices.	Difference in our favour.	Remarks.
	Rs.	Rs.	Rs.		Rs.	Rs.	Rs.	
Agra... ...	161·0	115·0	46·0		202·0	109·0	93·0	
Allahabad ...	163·0	110·2	52·8		204·0	104·2	99·8	
Benares ...	171·0	118·2	52·8		212·0	119·0	93·0	
Bhosawul ...	135·8	83·0	52·8		176·8	77·0	99·8	
Bombay ...	119·0	99·8	19·2		160·0	93·8	66·2	
Cawnpore ...	167·0	114·2	52·8		208·0	108·2	99·8	
Gwalior ...	170·0	124·0	4·60		211·0	118·0	93·0	
Jubbulpore ...	152·0	99·2	52·8		193·0	93·2	99·8	
Lahore ...	180·5	134·5	46·0		221·5	128·5	93·0	
Lucknow ...	171·0	118·2	52·8		212·0	112·2	99·8	
Mooltan ...	190·0	144·0	46·0		231·0	138·0	93·0	
Nagpore ...	148·5	75·3	73·2		189·5	69·3	120·2	
Neemuch ...	152·5	99·7	52·8		193·5	93·7	99·8	
Warora ...	149·5	69 3	80·2		190·5	63·3	127·2	

REMARKS.—The prices are given per ton, including freight; the latter is calculated at the rates for first class railway goods.

The English prices are given according to the market rates for March 1882, and are, of course, subject to the influence of the fluctuations of the prices in the European markets.

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COMPARATIVE STATEMENT

Showing the Difference of Prices of Iron and Steel Goods in different Railway Stations—continued.

Names of Stations.	Thin Hoop-iron and Rolled Wire.				"Low Moor" Plates.			
	English prices.	Our cost prices.	Difference in our favour.	Remarks.	English prices.	Our cost prices.	Difference in our favour.	Remarks.
	Rs.	Rs.	Rs.		Rs.	Rs.	Rs.	
Agra... ...	182·0	116·0	66·0		442·0	141·0	301·0	
Allahabad ...	184·0	111·2	72·8		444·0	136·2	307·8	
Benares ...	192·0	119·2	72·8		452·0	144·2	307·8	
Bhosawul ...	156·8	84·0	72·8		416·8	109·0	307·8	
Bombay ...	140·0	100·8	39·2		400·0	125·8	274·2	
Cawnpore ...	188·0	116·2	72·8		448·0	140·2	307·8	
Gwalior ...	191·0	125·0	66·0		451·0	150·0	301·0	
Jubbulpore ...	166·0	93·2	72·8		433·0	125·2	307·8	
Lahore ...	201·5	135·5	66·0		461·5	160·5	301·1	
Lucknow ...	192·0	119·2	72·8		452·0	144·2	307·8	
Mooltan ...	211·0	145·0	66·0		471·0	170·0	301·0	
Nagpore ...	169·5	76·3	93·2		429·5	101·3	328·2	
Neemuch ...	173·5	100·7	72·8		433·5	125·7	307·8	
Warora ...	170·5	70·3	100·2		430·5	95·3	335·2	

Names of Stations.	Thin Sheet-iron.				Blister Steel.			
	English prices.	Our cost prices.	Difference in our favour.	Remarks.	English prices.	Our cost prices.	Difference in our favour.	Remarks.
	Rs.	Rs.	Rs.		Rs.	Rs.	Rs.	
Agra... ..	182·0	118·0	64·0		342·0	145·0	197·0	
Allahabad ...	184·0	113·2	70·8		344·0	140·2	203·8	
Benares ...	192·0	121·2	70·8		352·0	148·2	203·8	
Bhosawul ...	156·8	86·0	70·8		316·8	113·0	203·8	
Bombay ...	140·0	102·8	37·2		300·0	129·8	170·2	
Cawnpore ...	188·0	118·2	70·8		348·0	144·2	203·8	
Gwalior ...	191·0	127·0	64·0		351·0	154·9	197·0	
Jubbulpore ...	166·0	95·2	70·8		333·0	129·2	203·8	
Lahore ...	201·5	137·5	64·0		361·5	164·5	197·0	
Lucknow ...	192·0	121·2	70·8		352·0	148·2	203·8	
Mooltan ...	211·0	147·0	64·0		371·0	174·0	197·0	
Nagpore ...	169·5	78·3	91·2		329·5	105·3	224·2	
Neemuch ...	173·5	102·7	70·8		333·5	129·7	203·8	
Warora ...	170·5	72·3	98·2		330·5	99·3	231·2	

REMARKS.—The prices are given per ton, including freight; the latter is calculated at the rates for first-class railway goods.

The English prices are given according to the market rates for March 1882, and are, of course, subject to the influence of the fluctuation of the prices in the European markets.

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COMPARATIVE STATEMENT

Showing the Difference of Prices of Iron and Steel Goods in different Railway Stations—Concluded.

Names of Stations.	Cast-iron Pipes. English prices.	Cast-iron Pipes. Our cost prices.	Cast-iron Pipes. Difference in our favour.	Cast-iron Pipes. Remarks.	Cast-iron Sleepers. English prices.	Cast-iron Sleepers. Our cost prices.	Cast-iron Sleepers. Difference in our favour.	Cast-iron Sleepers. Remarks.
	Rs.	Rs.	Rs.		Rs.	Rs.	Rs.	
Agra	117·0	92·0	25·0		98·0	87·0	11·0	
Allahabad ...	119·0	87·2	31·8		100·0	82·2	17·8	
Benares ...	127·0	95·2	31·8		108·0	90·2	17·8	
Bhosawul ...	91·8	60·0	31·8		72·8	55·0	17·8	
Bombay ...	75·0	76·8	...		56·0	71·8	..	
Cawnpore ...	123·0	91·2	31·8		104·0	86·2	17·8	
Gwalior ...	126·0	101·0	25·0		107·0	96·0	11·0	
Jubbulpore ...	108·0	76·2	31·8		89·0	71·2	17·8	
Lahore ...	136·5	111·5	25·0		117·5	106·5	11·0	
Lucknow ...	127·0	95·2	31·8		108·0	90·2	17·8	
Mooltan ...	146·0	121·0	25·0		127·0	116·0	11·0	
Nagpore ...	104·5	52·3	52·2		85·5	49·3	36·2	
Neemuch ...	108·5	76·7	31·8		89·5	71·7	17·8	
Warora ...	105·5	46·3	59·2		86·5	41·3	45·2	

Name of Station.	"Brescian" Steel. English prices.	"Brescian" Steel. Our cost prices.	"Brescian" Steel. Difference in our favour.	"Brescian" Steel. Remarks.	Ferromanganese, with 60 per cent Manganese. English prices.	Ferromanganese, with 60 per cent Manganese. Our cost prices.	Ferromanganese, with 60 per cent Manganese. Difference in our favour.	Ferromanganese, with 60 per cent Manganese. Remarks.
	lbs.	lbs.	lbs.		lbs.	lbs.	lbs.	
Sheffield ...	18·0	10·0	8·0		22·0	11·50	10·50	

REMARKS.—The prices are given per ton, including freight; the latter is calculated at the rates for first class railway goods.
The English prices are given according to the market rates for March 1882, and are of course subject to the influence of the fluctuations of the prices in the European markets.

APPROXIMATE ESTIMATE OF AN IRON WORK
PRODUCING 80 TONS BESSEMER STEEL RAILS PER DIEM.
See plans Nos. II & III.

1.—FURNACES AND MACHINERY—

(a)—*For the Blast Furnaces*—

	Rs.	Rs.	Rs.
3 Ore crushers		7,200	
2 Blowing engines, each giving 2,000 cubic feet air per minute, with 2 water-pumps—			
Machinery	54,000		
Foundations	10,000		
		64,000	
1 Hoist for iron ores, charcoal and limestone		18,000	

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	Rs.	Rs.	Rs.
12 Steam-boilers, each 40 horse power—			
Boilers	36,000		
Masonry	12,000		
		48,000	
3 Blast furnaces, each producing 33 tons of pig-iron per day—			
Cast and wrought iron	69,000		
Masonry	18,000		
		87,000	
6 Hot-blast ovens—			
Cast and wrought iron	18,000		
Masonry	6,000		
		24,000	
Regulator of blast, gas conduit, blastman, steam and water pipes, &c.—			
Cast and wrought iron	24,000		
Masonry	6,000		
		30,000	
2 Water reservoirs, each for 15,000 cubic feet contents ...		...15,000	
Cinder and ore tubs, scales, stools, &c.		...15,000	
			3,08,200
(b)—For the Bessemer and Rolling Mill—			
4 Gas furnaces—			
Cast and wrought iron	20,000		
Masonry	8,000		
		28,000	
2 Bessemer converters, each for 5 tons contents—			
Cast and wrought iron	15,000		
Masonry	2,000		
		17,000	
2 Cupola furnaces, including derrick—			
Cast and wrought iron	5,000		
Masonry	1,500		
		6,500	
3 Drying furnaces with crane—			
Cast and wrought iron	2,500		
Masonry	2,000		
		4,500	
1 Blowing engine—			
Machinery	36,000		
Foundation	6,000		
		42,000	
1 Water-pump with accumulator for the hydraulic machinery—			
Machinery	10,000		
Masonry	3,000		
		13,000	
1 Hydraulic crane for 10 tons maximum weight—			
Machinery	7,500		
Masonry	2,000		
		9,500	
3 Hydraulic cranes for 4 tons maximum weight—			
Machinery	5,000		
Masonry	1,500		
		6,500	

	Rs.	Rs.	Rs.
1 Blooming mill with 250 horse-power steam engine and 45 tons fly wheel—			
Machinery	70,000		
Foundation	8,000		
		78,000	
1 Rails mill with 300 horse-power steam engine and 40 tons fly wheel—			
Machinery	90,000		
Foundation	11,000		
		1,01,000	
1 Steam-hammer, including crane—			
Machinery	15,000		
Foundation	5,000		
		20,000	
16 Steam-boilers, each 40 horse-power—			
Boilers	48,000		
Masonry	16,000		
		64,000	
2 Water reservoirs, each for 15 cubic feet		15,000	
2 Water-pumps, including steam engine		6,000	
2 Feeding-pumps for the steam-boilers, including steam engine ...		3,200	
1 Large scale for weighing the Bessemer blocks—			
Machinery	2,500		
Masonry	1,500		
		4,000	
2 Circular saws with steam engine		3,000	
3 Drilling machines		4,500	
1 Punching machine		2,500	
1 Slotting "		1,500	
2 Straightening machines		5,000	
1 35 horse-power steam engine, including transmission—			
Machinery	4,000		
Foundation	600		
		4,600	
Cooling beds for rails		3,000	
Steam, water and air pipes		14,000	
Pans, railways, wagons, ingot-moulds, tools, &c		10,000	
			4,66,300
(c)—*For the Workshops*—			
1 Large lathe for the cylinders		5,000	
1 Small " "		1,500	
1 Planing machine		3,000	
1 Drilling "		1,200	
2 Root's blowers		2,400	
1 Steam engine of 40 horse-power, including transmission—			
Machinery	4,500		
Foundation	700		
		5,200	
2 Steam-boilers, each 20 horse-power—			
Boilers	3,600		
Masonry	1,200		
		4,800	

	Rs.	Rs.	Rs.
1 Crane		5,000	
1 Cupola furnace with derrick—			
Cast and wrought iron	2,000		
Masonry	600		
		2,600	
Tools, pipes, railways, &c.		4,000	
			34,700

II.—BUILDINGS—

(a)—For the Blast Furnaces—

	Area in square feet.		
3 Charcoal shops	30,000	30,000	
Store-yards for iron ores, coal and limestone	40,000	7,500	
Ore-crush and ore-mixing house	3,000	6,000	
2 Blowing engine-houses	5,000	15,000	
Building for the hoist	800	8,000	
Foundry hall	15,000	22,500	
2 Chimneys, each 120 feet high	500	8,000	
Channels and drains		6,000	
			1,03,000

(b)—For the Bessemer Mill—

Bessemer and rolling mill	1,00,000	2,50,000	
2 Chimneys, each 120 feet high	500	8,000	
Channels and drains		6,000	
			2,64,000

(c)—For the Workshops and divers other buildings—

2 Workshops	20,000	40,000	
Store-room	4,000	8,000	
Scale and porter-house, including scale	1,500	5,000	
Office	7,000	14,000	
3 Dwelling-houses for Engineers	12,000	18,000	
3 Barracks for workmen	18,000	24,000	
1 Chimney for workshops, 80 feet high	150	1,000	
Drains and channels		1,000	
			1,11,000

III.—EARTHWORK—

Levelling ditches, tanks, dams, &c.			20,000

IV.—TRAMWAYS—

55 *running miles* tramway to connect Lohara and Warora with the Iron work. 20 *running miles* for transport of charcoal to the Iron work, altogether 75 miles tramway, per mile	12,000	...	9,00,000

V.—WORKING CAPITAL—

Amount invested in stores		1,50,000	
Reserve funds		1,50,000	
			3,00,000

VI.—ENGAGEMENT AND BRINGING OUT OF 70 EUROPEAN WORKMEN 35,000

Recapitulation

Cost of furnaces and machinery	8,09,200	
Do building and earthwork	4,98,000	
Do tramways (75 miles)	9,00,000	
Do bringing out European workmen	35,000	
Working Capital and Reserve funds	3,00,000	
Total...	25,42,000	25,42,000

An Iron work producing 80 *tons Bessemer steel rails per day costs Rs.* 25,42,000.

(See Appendix No. 7, page 28.)

APPROXIMATE ESTIMATE OF AN IRON WORK

PRODUCING 8 TONS OF PUDDLED BAR-IRON, HOOP-IRON, THIN SHEET-IRON, AND ROLLED WIRE PER DAY.

(*See Plan No. IV.*)

	Rs.	Rs.	Rs.
I.—FURNACES AND MACHINERY—			
(*a*)—*For the Blast Furnaces*—			
The same as for the Bessemer work (see page 19)			3,08,200
(*b*)—*For the Puddling and Rolling Mill*—			
38 Puddling furnaces—			
Cast and wrought iron	53,200		
Masonry	22,800		
		76,000	
10 Heating furnaces—			
Cast and wrought iron	20,000		
Masonry	10,000		
		30,000	
2 Reheating furnaces—			
Cast and wrought iron	1,000		
Masonry	500		
		1,500	
24 Steam-boilers—			
Boilers	72,000		
Masonry	24,000		
		96,000	
6 Steam-hammers—			
Machinery	54,000		
Foundation	18,000		
		72,000	
3 Puddling trains—			
Machinery	72,000		
Foundation	9,000		
		81,000	
1 Bar-iron train—			
Machinery	30,000		
Foundation	3,000		
		33,000	
1 Sheet-iron train—			
Machinery	40,000		
Foundation	5,000		
		45,000	
1 Hoop-iron train—			
Machinery	30,000		
Foundation	3,000		
		33,000	
1 Wire train—			
Machinery	36,000		
Foundation	4,000		
		40,000	

		Rs.	Rs.
2 Double shears for puddle-bars		6,000	
1 Double shear for bar-iron		2,500	
1 " " sheet-iron		3,000	
1 Circular shear for sheet-iron...		1,500	
3 Water reservoirs, each for 10,000 cubic feet		16,000	
3 " pumps with steam engines		6,000	
3 Feeding pumps for boilers		4,800	
Steam and water pipes, &c.		14,000	
Tools, railways, wagons, &c.		10,000	
			5,71,300
(c)—For the Workshops—			
2 Large lathes for cylinders		8,000	
2 Smaller " "		5,000	
The other machinery is the same as for the Bessemer work ...		29,700	
			42,700
II.—BUILDINGS—			
(a)—For the Blast Furnaces—			
The same as for the Bessemer work			1,03,000
	Area in square feet.		
(b)—For the Puddling and Rolling Mill—			
Puddling mill...	82,000	1,64,000	
Rolling mill	42,000	84,000	
9 Chimneys, each 100 feet high	2,000	22,500	
Channels and drains	...	6,000	
			2,76,500
(c)—Workshops and divers buildings—			
The same as for the Bessemer work			1,11,000
III.—EARTHWORK—			
Levelling ditches, tanks, drains, &c.			20,000
IV.—TRAMWAYS—			
75 running miles (as before), per mile Rs. 12,000			9,00,000
V.—ENGAGEMENT OF 70 EUROPEAN WORKMEN			35,000
VI.—WORKING CAPITAL—			
Amount invested in stores			1,50,000
Reserve Funds			1,50,000

Recapitulation.

Furnaces and machinery	9,22,200	
Buildings and Earthwork	5,10,500	
Tramways	9,00,000	
Working Capital and Reserve Funds	3,00,000	
Engagement of European workmen	35,000	
Total	26,67,700	26,67,700

An Iron Work producing 80 tons per day of puddled bar-iron, thin sheet-iron, hoop-iron, and rolled wire costs Rs. 26,67,700.

(See Appendix No. 7, page 28.)

APPENDICES.

No. 1.—The proportion of the pig-iron to the slags in the blast furnace should not exceed that of 5 : 1. The reason of this is that the pig-iron, which accumulates in the lowest part of the blast furnace, requires to be protected from the decarbonising effect of the blast streaming out of the tuyeres. This protection is offered by a sufficiently thick layer of slags, which being specifically lighter, floats on the surface of the pig-iron bath like oil on water, keeping off every injurious action of the air hovering over it. As a rule, the quantity of slags is twice and three times as large as that of the pig-iron. In the smelting of the Lohara ores, the decidedly rare case presents itself of the ores being too pure and the blast furnace slags consisting of the impurities of the ores, the ashes of the fuel and of the flux, representing 16 per cent only of the quantity of pig-iron. To complete, therefore, the deficiency of 4 per cent, the ore of Lohara require an addition of 12 per cent of an inferior ore, which is to be found in the neighbourhood of the projected Iron Work.

The reason of the difficulty in treating magnet iron ores lies in general in their low melting point combined (notwithstanding their proportionally smaller contents of oxygen) with a difficulty in reduction. On this account it easily occurs that magnetites begin to melt in the blast furnace before the oxygen has been driven out, bringing about the unpleasant consequences well known to iron-masters. Magnetites can therefore not be worked with a blast of high temperature in order to reduce them, as much as possible with carbonic oxygen gas (CO), that is to say, at a lower temperature.

Therefore, also, for the smelting of magnetite ($Fe_3\ O_4$) proportionately larger consumption of fuel in the blast furnace is required than in the smelting of specular iron ores ($Fe_2\ O_3$), a kind of red iron ore, although the latter requires more carbon for its reduction than the former.

No. 2.—The reasons why specifically heavier charcoal, weight for weight, is more valuable than specifically lighter charcoal are the following:—

(1) A larger quantity of fixed carbon is comprised in a smaller space, whereby, as is well known, the pyrometric effect of every description of fuel is raised.

(2) The larger the specific weight is of charcoal, the greater is its resistance to being crushed, and this consideration is very important in regard to the use of charcoal in the blast furnace. In general, the dimensions of a blast furnace should be *as large as possible*, as thereby fuel, labour, and wear and tear are spared, but their limit is determined by the height of the furnace from which all the other dimensions depend. The height of a blast furnace again depends on the mechanical resistance "capacity" of the fuel to be used, which "capacity" should be great enough to enable it to bear, in the lower parts of the furnace, the whole weight of the smelting column which fills the furnace, (namely, the ore, fuel and flux) without being crushed. Coke furnaces are worked most economically, because their height reaches 70 feet, and their outturn of pig-iron can be raised to 75 tons per day. The charcoal blast furnaces of Styria and Sweden have a miximum height of 45 feet, and produce 20 tons of pig-iron, but the charcoal of Chanda will allow of a blast furnace 52 feet high capable of turning out daily from 30 to 35 tons of pig-iron.

No. 3.—Coke for the blast furnace process should not be smaller than half a fist; it is better when the pieces are more than the size of a first, and this on the following grounds:—

(1) To facilitate their onward motion, together with the ore and flux, which is necessary for the promotion of the chemical reactions between the fuel, ore and flux as they sink in the blast furnace, which chemical reactions are possible only when the materials remain in constant touch with one another.

(2) To render possible the withdrawing of the gases rising from the lower parts of the blast furnace, which evidently would not take place if all the interstices between the materials which fill the blast furnace were choked up with small particles of coke.

No. 4.—It may not be out of place here to meet an objection arising from an opinion still often entertained, that for the purpose of producing "Spiegeleisen," manganese ores may be added to iron ores devoid of it by introducing it into the blast furnace in proper quantities along with the iron ore.

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This question may be raised in our case, as manganese ore is found not far from the Iron Work (see Plan No. I, page 10). All such attempts have failed in practice, owing to the difficulty of reducing manganese ore. It is found that the iron ore is reduced (the oxygen driven out) and carbonised; therefore ready for the melting process, when the manganese ore, which had been put in simultaneously with the other, has scarcely commenced giving off its oxygen; in other words, has scarcely commenced to be reduced.

The natural consequence then results that the manganese ore (reaching the melting zone almost unchanged) is fused in this condition, and forms a good part of the blast furnace slags without amalgamating itself with the pig-iron.

The simultaneous reduction of oxide of manganese and oxide of iron can only take place when the particles of both are most intimately mixed, which is the case in iron ores containing a large percentage of oxide of manganese.

An alloy of metallic iron and manganese, the so-called ferromanganese, can be obtained by certain manipulations (see page 9); but has ferromanganese cannot replace "Spiegeleisen," this process is not worth further consideration in *this* place.

No. 5.—The direct process of Siemen's is, under the conditions before us, not suitable, because this process depends also upon the open-hearth furnace, as the iron blooms (the end product of the Siemen's rotator furnace) have to be dissolved in the pig-iron bath of the open-hearth for the conversion into steel. These blooms are therefore used in the same manner as the iron ores in the Landore process.

Should, however, in future the open-hearth process become practicable (through opening of the Pisgaon coal mine—see page 4), it is then the *Landore* direct process would be preferable, as, in our case, the iron ores of Lohara would cheaply replace the iron blooms of Siemen's rotator.

No. 6.—For the reasons explained in page 27, an addition of 12 per cent of poorer ores will be necessary for the Lohara ores. Such poorer ores are to be found in Joonona, about 19 miles from the Iron Work, therefore about 20 miles nearer than those of Lohara; but as the former have to be carried by cart to the Iron Work, the price of Rs. 3½ (delivered at the works) remains unaltered.

No. 7.—The estimate includes the cost of the tramway for the transport of the charcoal to the Iron Work. The length of this tramway would be 20 miles, and its price Rs, 2,40,000. In the first seven years, however, the charcoal might be carried on the other tramway, *viz.*, that connecting the Iron Work with Lohara and Warora, and the building of the charcoal tramway might be deferred till the necessary rails, sleepers, &c., can be made in our own Iron Work.

No. 8.—*Cost per ton of manufactured charcoal from the Mahorli forests, at the place of production, for iron work.* (*The dates are furnished by the Conservator of Forests, Central Provinces.*)

When the yield per square mile is tons charcoal.	Felling and collection of wood and manufacture of charcoal.			Cultural operations for maintenance of yield.			Establishment.			Wear and tear of building and stock.			Total.			Allowing for rise in wages and contingencies to be expected 30 per cent.			Remarks.
	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.	
2,000	3	9	0	1	12	0	0	10	0	0	3	0	6	2	0	8	0	0	
3,000	2	12	8	1	2	0	0	10	0	0	3	0	4	11	8	6	2	8	
4,000	2	1	0	0	12	0	0	10	0	0	3	0	3	10	0	4	11	4	
6,000	1	7	2	0	8	0	0	10	0	0	3	0	2	12	2	3	10	0	
10,000	0	15	4	0	5	0	0	10	0	0	3	0	2	1	4	2	12	0	
Average...	2	2	8	0	14	2	0	10	0	0	3	0	3	13	10	5	0	6	

No. 9 —Memorandum showing the principal species of trees occurring in the Chanda forests which are permitted to be felled for consumption.

Botanical Names.	Hindustani Names.	Weight per cub. ft. in lbs.	Remarks.
Acacia Leucophloa	Reunja	55	*
Do. Catechu	Khair	75	*
Adina Cordifolia	Haldu	42	
Albizzia Lebbek	Sirrus	52	
Do Lucida	Sirrus	40	
Do Odorotissima	Basseni Sirrus ...	40	
Do Procera...	Safed Sirrus... ...	42	*
Bauhinia Retusa	Bhoti	54	*
Do Variegata	Kachuar	54	
Do Malabarica	Amlosa	42	
Barringtonia Acutangula	Salamandar Phal ...	56	
Bombax Malabaricum	Semal	29	
Boswellia Thurifera	Satai	33	
Butea Frondosa	Palus	34	
Cassia Fistula	Amaltas	59	
Cochlospernum Gossypium	Gadbi	30	
Conocarpus Latifolia	Dhawra	61	
Diospyrus Melanoxylon	Pendu	75	
Gardenia Turgida	Ghuga	56	
Feronia Elephantum	Kawity	50	
Gardenia Gummifera	Dekarmali	54	
Do Lucida	Do	54	
Do Latifolia	Papra	52	
Grewia Oppositifolia	Bihul	40	
Do Vestita	Dhamin	50	
Helicteris Isora...	Maror Phal	40	
Ixora Parviflora...	Lokhandi	45	
Kydia Calysina	Baranja	42	
Lebidicropsis Orbicularis	Jarari	45	
Legerstrœmia Parviflora	Leudia	45	*
Limonia Acidissima	Bali	60	
Nauclea Parviflora (Stephegine)	Keim	41	*
Odina Wodier	Ghujah or Moru ...	55	
Phyllanthus Emblica	Amla	55	
Sleichera Trijuga	Kusam	68	*
Soymida febrifuga	Rohan	65	*
Sterculia Urens	Kulu	35	
Terminalia Bellerica	Bahera	41	
Xylia Dolabriformis (Ironwood of Burma) ...	Tamba	64	
Zizyphus Xylopyra	Ghoti	60	*

1. Average weight per cubic foot 50 lbs.
* 2. Require special sanction of the Deputy Commissioner for being cut.
3. The names of the trees have been furnished by Geo. Taylor, Esq., Assistant Conservator of Forests at Chanda.

SUGGESTIONS.

The quantities, qualities, and the prices of the raw materials available in the Chanda district would furnish daily 80 tons of finished iron or steel, saleable at competition and profitable prices in India, and certain other articles for exportation to England.

Rails would give the *smallest* profit, as, by the "Thomas Gilchrist" dephosphorising method combined with the Bessemer process, the cheaper pig-iron, containing phosphorus, is worked into rails, the price of which has therefore fallen in Europe by 40 per cent within the last two years.

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Greater will be the profit from kinds of iron which, for the reasons explained on page 8, cannot be made so profitably by means of the Bessemer process, such as small bar-iron, hoop-iron, thin sheet-iron, wire, &c.; in short, all such kinds of goods which have either a small or a complex section.

Most profitable in our case will be articles which can be made *only* of ores of the best quality, and with vegetable fuel. Some of these have been severally and briefly treated of on pages 6 and 7. The chief factor which may, in the beginning, mar the full financial success of the Chanda Iron Works lies in the high railway freight prevailing in India.

This incubus on iron-work industry will, in the present case, press all the harder, as the railways of the Central Provinces are still insufficiently developed, as a glance at the railway chart may easily prove; but it may be expected that commercial, strategical, and other interests will soon cause the completion of the system to be taken in hand.

In the interest of the prospective iron industries of Chanda, the following extensions or new constructions of railways would be beneficial :—

(1) An extension of the Wardah-Warora line to Hyderabad *viâ* Chanda.

(2) A junction of the Great Indian Peninsula line at Kamptee with Gadawara or Jubbulpore (Bhosawul-Jubbulpore line) *viâ* Seoni.*

(3) A farther extension of the latter line through Saugor and Jhansi and a junction with Gwalior.

Should these extensions be decided upon, it would be advisable to utilize the natural resources of the Chanda district in iron works capable of manufacturing all the iron railway material.

* North-east of Nagpore.

CHANDA;
19*th April* 1882.

RITTER C. VON SCHWARZ.

Abstract of Season or Intermediate Reports for the Week ending 23*rd September* 1882.

Bangalore District.—Rain-fall, 1 inch 78 cents in the Cantonment and 1 inch 15 cents in the Pettah of Bangalore. Crops in good condition having been much benefited by timely showers. Prospects of season favorable. Public health good, but fever and small-pox continue to prevail in parts of the District. Drinking water and pasturage ample. Murrain still prevalent in the Taluks of Devanhalli and Magadi. Prices: rice 11⅛ seers, ragi 30¼ seers, and horse-gram 31¾ seers per rupee.

Kolar District.—Sixty-nine cents of rain at Kolar. Seasonable rain has fallen throughout the District benefiting the crops. More rain needed. Sowing of horse-gram, hutchellu, yedigar paddy and green-gram continued. A small quantity of gingelly seed and sajje was harvested. Tanks have not yet received a full supply of water. Public health good. Cattle in a healthy condition generally. Fodder ample. Prices: rice 12½ to 13¼ seers and ragi 28 to 32 seers per rupee.

Tumkúr District.—Five inches 69 cents of rain at Tumkúr. Heavy showers have also fallen throughout the District. Standing crops in good condition. Arecanut and cocoanut were gathered in some taluks, and javari and sesamum reaped in others. Paddy and horse-gram were sown. Prospects of season improving. Public health good. Cattle are in good condition. Drinking water and pasturage sufficient. Prices: rice 11 to 14 seers, ragi 32 to 38 seers and horse-gram 36 to 40 seers per rupee.

Mysore District.—Three inches 87 cents of rain at Mysore. The rains have been very beneficial to crops especially to ragi. Green and black-gram, paddy, horse-gram, sáme, &c., were sown. Kar-ragi, gingelly seed and cholam were harvested. Public health good. Prices: rice 12½ seers, ragi 22¾ seers and horse-gram 33⅓ seers per rupee.

Hassan District.—Two inches 31 cents of rain at Hassan. Standing crops in good condition, excepting gid-ragi in the Hassan Taluk which is suffering from excessive rain, and the dry crops in one hobli of the Haranhalli Taluk which are suffering from the want of rain. Ragi, jola and sesamum were harvested in parts. Prospects of season favorable. Public health good. Small-pox and fever however

prevalent in parts. Cattle are in a healthy condition, but murrain prevalent in some parts. Water supply and pasturage abundant. Prices: rice 2nd sort 10 to 15 seers, ragi 22 to 34 seers, and horse-gram 20 to 50 seers per rupee.

Shimoga District.—Three inches 29 cents of rain at Shimoga. Standing crops in good condition. Horse-gram, green and black-gram and navane, were sown. Paddy seedlings were transplanted in Ságar and Kavaledurga, baragu, green and black-gram harvested in Channagiri and Shikarpur. Areca-nut is being picked in Ságar. Prospects good. Fever, lung affections and dysentery prevalent. Prices: rice 13 to 18 seers, ragi 20 to 40 seers and jola 24 to 36 seers per rupee.

Kadur District.—One inch and 3 cents of rain at Chikmagalur. Standing crops, *viz.*, paddy, ragi, avare, horse-gram, jola, oil-seed, wheat, and togari, in good condition. Horse-gram, togari, ragi and paddy were sown. Jola, oil-seed and gid-ragi were harvested. Prospects of season and public health, good. Murrain prevalent in parts of the Tarikere Taluk. Pasturage and water-supply plentiful. Prices: rice 12 to 14 seers and ragi 22 to 28 seers per rupee.

Chitaldroog District.—Sixty-five cents of rain fell at Chitaldroog. Standing crops in good condition except in portions of the Pavagada, Budihal and Dodéri Taluks where they are fading. Javari, gingelly, black and green-gram, wheat, baragu and navane were harvested. Cotton, sajje, horse-gram, &c., were sown. Prospects of season and public health good. Murrain prevalent in parts. Fodder and water-supply sufficient except in some villages of the Budihal Taluk. Prices: rice 10 to 14 seers, ragi 32 to 55 seers and javari 32 to 54 seers per rupee.

By Order,

R. Vijayindra Rao,

Secretary.

Prices current of Food Grains in the Province of Mysore during the Fortnight ending 15*th* *September* 1882.

QUANTITY PER RUPEE BY THE STANDARD SEERS OF 80 TOLAS, *vide* GOVERNMENT OF INDIA NO. 1—21, DATED 10TH FEBRUARY 1874.

Fortnight ending—15th September 1882

No.	Districts.	Sort.	Wheat. Present Fortnight. Seers.	Chitaks.	Past Fortnight. s.	c.	Corresponding Fortnight in 1881. s.	c.	Barley. Present Fortnight. s.	c.	Past Fortnight. s.	c.	Corresponding Fortnight in 1881. s.	c.	Rice, best sort. Present Fortnight. s.	c.	Past Fortnight. s.	c.	Corresponding Fortnight in 1881. s.	c.
1	Bangalore,	Wholesale.	11	3	11	11	12	4	12	14	13	3	13	4	10	7	10	7	10	[illegible]
		Retail.	10	11	11	2	11	12	12	5	12	11	12	12	9	14	9	14	10	[illegible]
2	Kolar ...	Wholesale.	...	...	...	...	...	...	11	5	10	6	11	5	14	3	14	3	11	[illegible]
		Retail.	...	...	...	...	...	...	11	1	10	2	11	1	13	15	13	15	10	[illegible]
3	Tumkúr ...	Wholesale.	14	8	14	8	17	0	13	0	13	0	12	8	12	8	12	8	12	8
		Retail.	14	0	14	0	16	0	12	6	12	8	12	0	12	0	12	0	12	0
4	Mysore ...	Wholesale.	12	8	12	8	10	12	...	...	...	...	11	4	11	0	11	4	10	4
		Retail.	12	0	12	0	10	8	...	...	...	...	11	[illegible]	10	12	11	1	10	0
5	Hassan ...	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	10	8	10	8	12	0	11	0	11	0	13	0	10	0	[illegible]	8	12	0
6	Shimoga .	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	13	10	12	10	12	10	14	11	13	10	13	10	11	9	10	8	10	8
7	Kadur ...	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	15	0	15	0	9	0	14	0	14	0	12	0	11	0	11	0	14	0
8	Chitaldroog.	Wholesale.	14	0	14	0	14	0	16	0	16	0	16	0	11	0	11	0	11	0
		Retail.	14	0	14	0	14	0	16	0	16	0	16	0	11	0	11	0	11	0
	Average ...	Wholesale.	13	1	13	3	13	8	13	5	13	2	12	14	11	13	11	14	11	1
		Retail.	12	13	12	12	12	4	13	1	12	14	12	11	11	4	11	4	11	5

No.	Districts.	Sort.	Rice, common. Present Fortnight. s.	c.	Past Fortnight. s.	c.	Corresponding Fortnight in 1881. s.	c.	Great Millet, (Jola, Javar) *Holcus Sorghum*. Present Fortnight. s.	c.	Past Fortnight. s.	c.	Corresponding Fortnight in 1881. s.	c.	Bulrush Millet, (Kambu, Bajra) *Penicillaria Spicata*. Present Fortnight. s.	c.	Past Fortnight. s.	c.	Corresponding Fortnight in 1881. s.	c.
1	Bangalore,	Wholesale.	[illegible]	[illegible]	11	11	12	0	29	0	27	5	26	12	...	...	...	...	...	...
		Retail.	[illegible]	[illegible]	11	2	11	8	27	14	26	5	25	12	...	...	...	...	...	...
2	Kolar ...	Wholesale.	15	7	15	7	13	9	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	[illegible]	3	15	3	13	5	...	...	...	...	...	...	...	...	...	...	...	...
3	Tumkúr ...	Wholesale.	13	8	13	8	13	8	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	13	0	13	0	13	0	...	...	...	...	...	...	...	...	...	...	...	...
4	Mysore ...	Wholesale.	11	8	12	0	10	[illegible]	25	0	25	0	...	...	...	...	...	...	...	...
		Retail.	11	4	11	12	10	8	21	0	24	0	...	...	...	...	...	...	...	...
5	Hassan ...	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	11	0	11	8	13	0	...	...	...	...	...	...	...	...	...	...	...	...
6	Shimoga .	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	13	10	12	10	12	10	29	6	31	8	36	12	...	...	...	...	...	...
7	Kadur ...	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	14	0	13	0	16	0	...	...	...	...	...	...	...	...	...	...	...	...
8	Chitaldroog.	Wholesale.	13	0	13	0	12	0	43	0	40	0	40	0	28	0	28	0	23	0
		Retail.	13	0	13	0	12	0	40	0	33	0	40	0	23	0	23	0	23	0
	Average ...	Wholesale.	15	6	13	2	12	6	34	0	30	12	33	6	23	0	23	0	28	0
		Retail.	12	12	12	10	12	14	[illegible]	5	29	7	34	3	23	0	28	0	28	0

No.	Districts.	Sort.	Lesser Millets, Ragi, &c., (Kavaru, Varagu, Save, China, Koralu, Marwa, Nagli, &c.) *Panicum Miliaceum, Eleusine, Coracana, &c.* Present Fortnight. s.	c.	Past Fortnight. s.	c.	Corresponding Fortnight in 1881. s.	c.	Gram. Present Fortnight. s.	c.	Past Fortnight. s.	c.	Corresponding Fortnight in 1881. s.	c.
1	Bangalore,	Wholesale.	27	12	27	8	26	12	31	5	32	0	34	2
		Retail.	23	12	26	7	25	12	30	5	31	0	33	2
2	Kolar ...	Wholesale.	32	7	32	7	32	4	34	8	33	6	36	12
		Retail.	32	2	32	2	32	0	34	8	33	1	36	8
3	Tumkúr ...	Wholesale.	36	0	33	0	36	0	40	0	38	0	40	0
		Retail.	35	0	32	0	35	0	39	0	37	0	39	0
4	Mysore ...	Wholesale.	21	8	22	8	20	8	31	0	31	0	31	0
		Retail.	21	0	22	0	20	0	30	0	30	0	30	0
5	Hassan ...	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	24	0	24	0	28	0	30	0	27	0	32	0
6	Shimoga .	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	29	15	31	0	38	14	30	7	29	6	35	3
7	Kadur ...	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...
		Retail.	25	0	25	0	29	0	23	0	23	0	32	0
8	Chitaldroog.	Wholesale.	42	5	45	0	45	5	32	0	30	0	32	0
		Retail.	40	5	40	0	45	5	30	0	30	0	32	0
	Average ...	Wholesale.	32	0	32	1	32	8	33	12	32	14	34	12
		Retail.	29	4	29	1	31	12	30	14	30	1	33	12

No.	Districts.	Sort.	Firewood. Present Fortnight. s.	c.	Past Fortnight. s.	c.	Corresponding Fortnight in 1881. s.	c.	Salt. Present Fortnight. s.	c.	Past Fortnight. s.	c.	Corresponding Fortnight in 1881. s.	c.	Description.
1	Bangalore,	Wholesale.	...	...	...	...	...	...	13	8	13	0	10	8	Sea salt.
		Retail.	96	0	96	0	84	0	13	0	12	12	10	0	
2	Kolar ...	Wholesale.	...	...	...	...	...	...	13	8	13	8	1	5	Do
		Retail.	172	6	172	6	172	6	13	3	13	3	1	1	
3	Tumkúr ...	Wholesale.	360	0	360	0	360	0	12	8	12	8	9	8	Do
		Retail.	340	0	340	0	340	0	12	0	12	0	9	0	
4	Mysore ...	Wholesale.	75	0	75	0	87	0	8	8	8	8	7	10	Do
		Retail.	72	0	72	0	84	0	8	4	8	[illegible]	7	8	
5	Hassan ...	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...	Do
		Retail.	500	0	600	0	600	0	8	0	9	0	7	8	
6	Shimoga .	Wholesale.	...	...	...	...	...	...	11	0	14	0	...	...	Do
		Retail.	480	0	48[illegible]	0	48[illegible]	[illegible]	[illegible]	[illegible]	10	8	8	15	
7	Kadur ...	Wholesale.	...	...	...	...	...	...	...	...	...	...	...	...	Do
		Retail.	64	0	64	[illegible]	64	0	11	0	11	0	9	0	
8	Chitaldroog.	Wholesale.	100	0	100	0	100	0	10	0	12	0	16	0	Earth salt.
		Retail.	100	0	[illegible]	[illegible]	100	0	10	0	12	0	16	0	
	Average ...	Wholesale.	178	5	173	5	182	5							
		Retail.	228	1	240	9	240	9							

MYSORE DEWAN'S OFFICE,
BANGALORE, 27*th* *September* 1882.

By Order,

R. VIJAYINDRA RAO,
Secretary.

Mysore Government Press, Bangalore—1882.